APEX EXPO IPC

NEW IDEAS … FOR NEW HORIZONS

MARCH 25-27, 2014
MANDALAY BAY RESORT AND CONVENTION CENTER
LAS VEGAS, NEVADA

NAMICS The leading company of conductive and insulating materials for electronics
NAMICS CORPORATION

Packaging Materials for 2.5/3D

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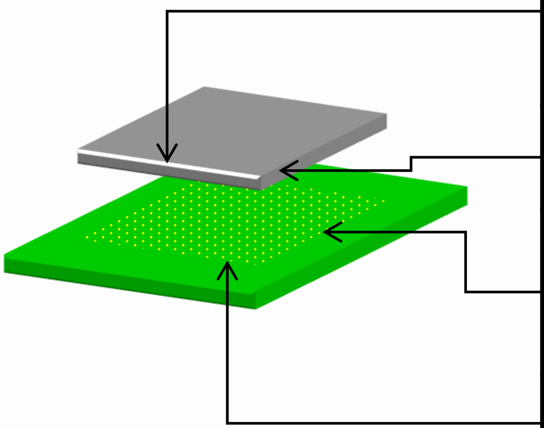
- Vacuum Assisted Process for CUF
- Overview of Pre-Applied Underfill
- NCP/TCCUF/NCF/BNUF Technology & Line-Up

Technological Transition in FCBGA Packages



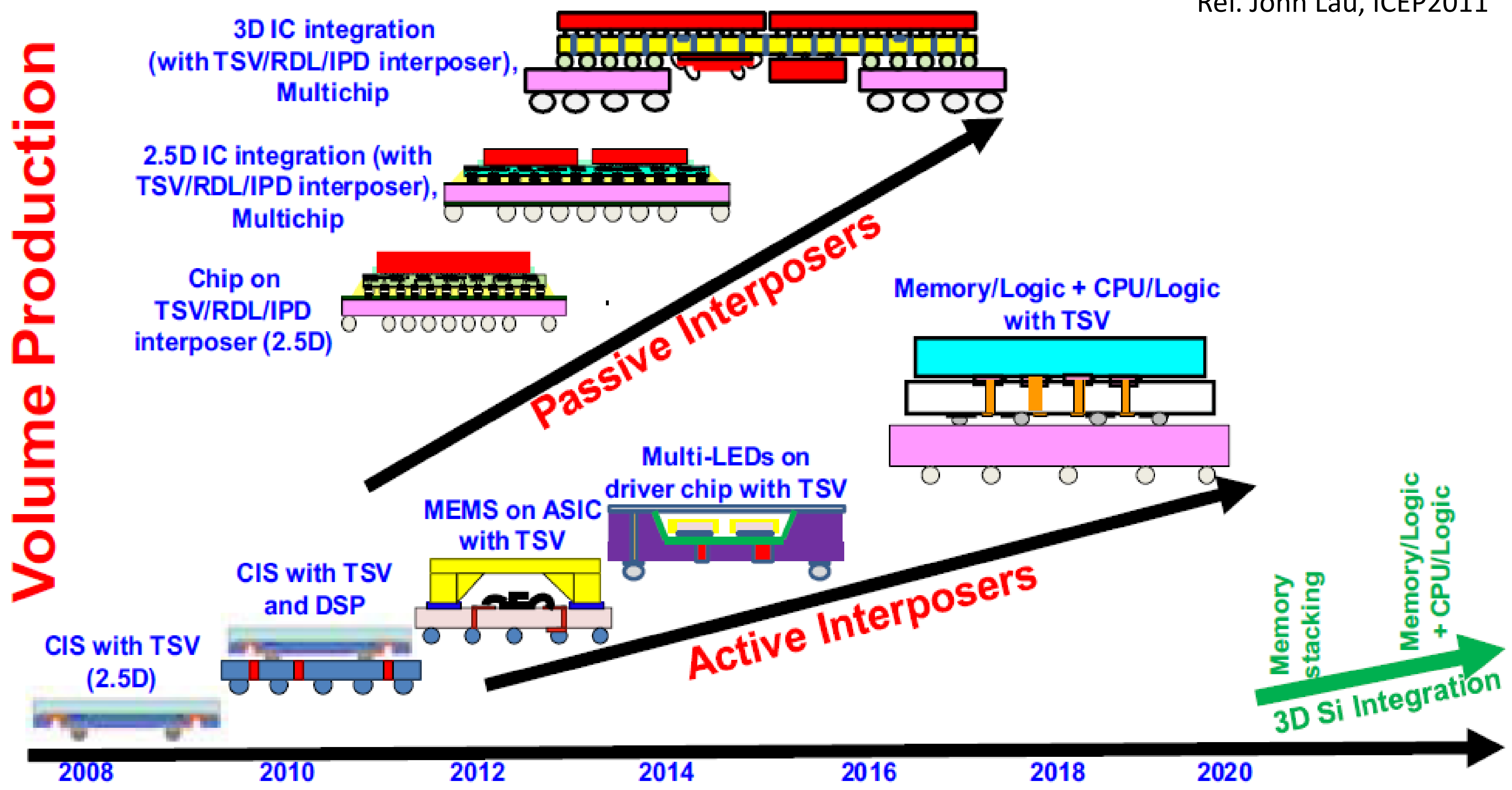
Year	**2012**	**2013**	**2014**	**2015**
Process generation & LowK generation (nm)	32/28	22/20		16/14
Maximum Die size (mm)	20x20 to 26x26 – FC-BGA 10x10 to 15x15 – FC-CSP			
Interconnection	Eu	Lead free		Cu-Pillar
Interconnection pitch (um)	130	120	<120	

Trend / **Concern**

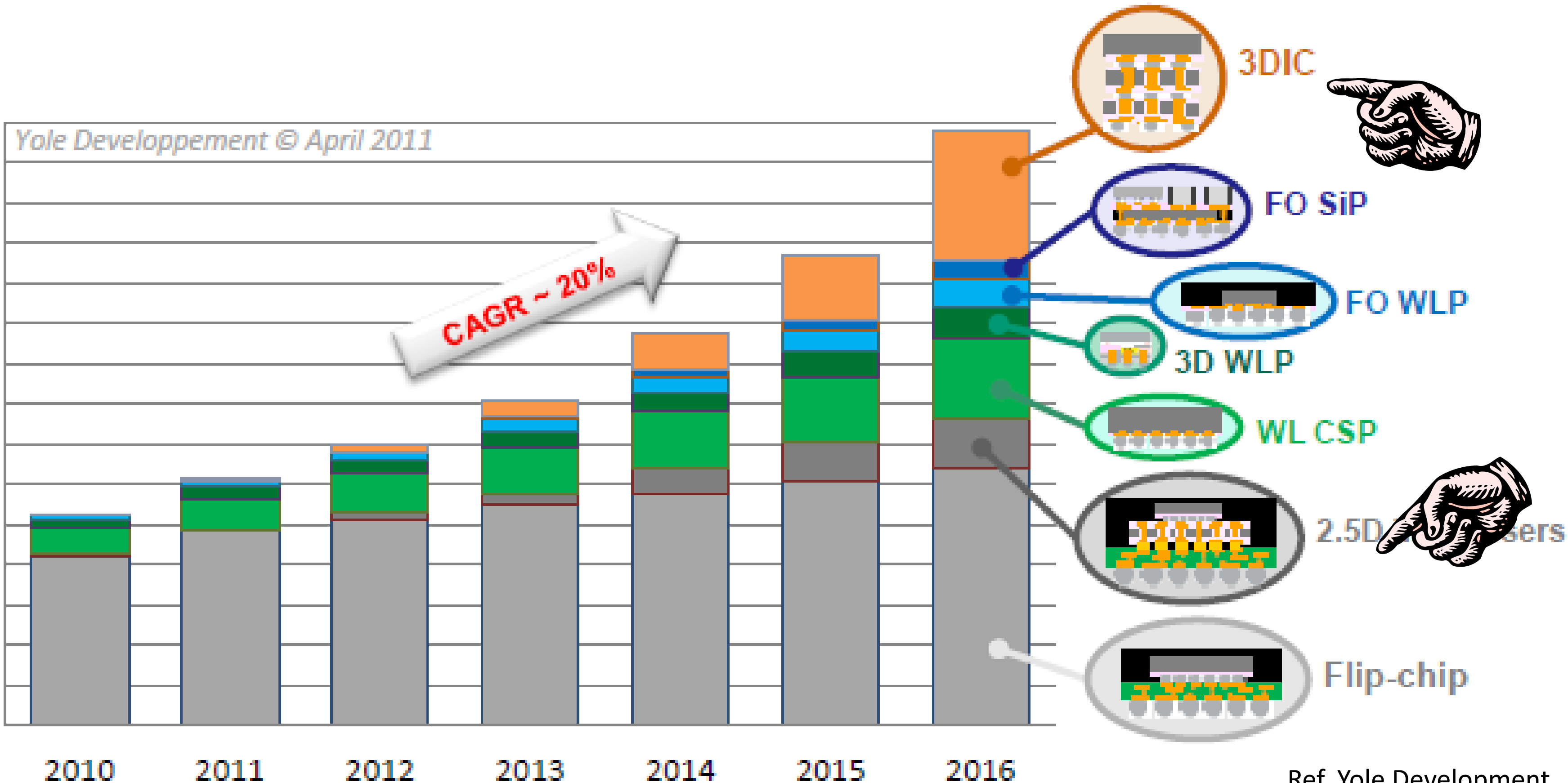
- Using fragile ultra low-k layers → Low-k crack
- Using lead-free solder with high rigidity → Bump crack
- Using Cu pillar → Filler separation

2.5D / 3D Integration Roadmap

Ref. John Lau, ICEP2011



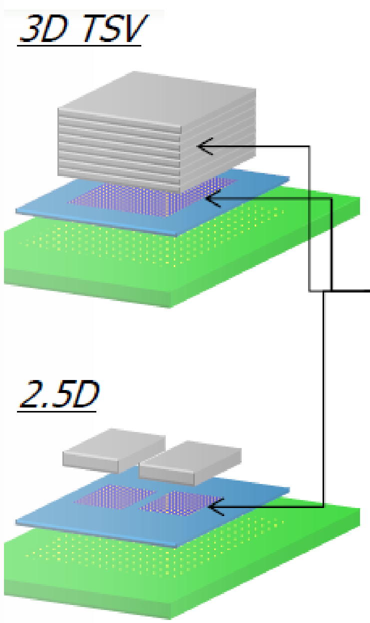
Global Wafer-Level-Packaging Trend



Ref. Yole Development

Wafer-level-packages have emerged as the fastest growing semiconductor packaging technology with more than 27% CAGR [compound annual growth rate] in unit shipments over the next 5 years to come.

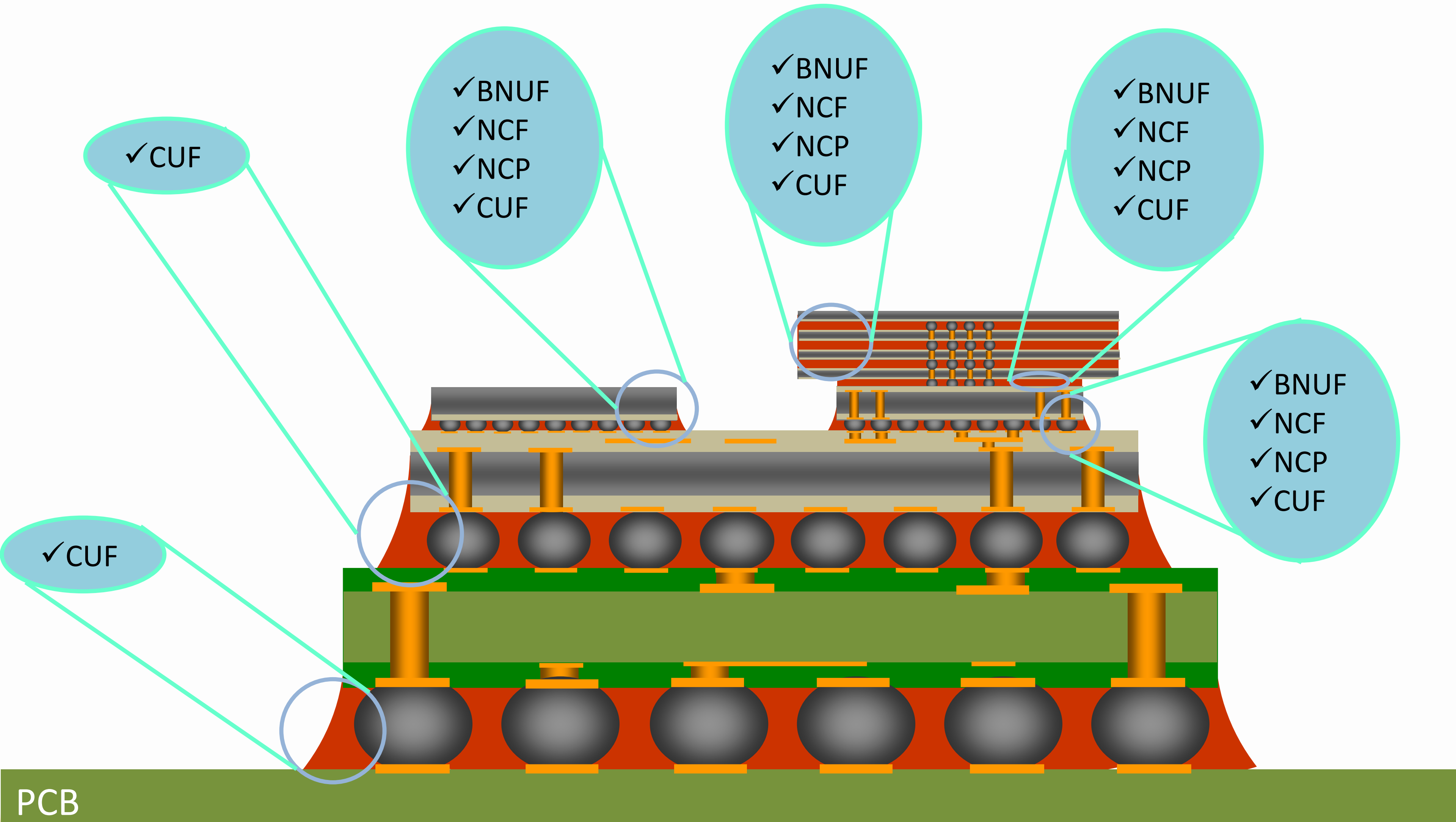
NextGen Package Trend – Material Properties



2.5D/3D Packaging trend				
Year	2012	2013	2014	2015
Microbump gap (um)	20 - 30			<20

Underfill development target for 2.5D/3D Packaging				
Year	2012	2013	2014	2015
Filler size (um)	0.3 ~ 0.6			0.3
CTE (ppm/C)	30 ~ 40			20 ~ 30
Thermal conductivity (W/m.K)	< 2.0			> 2.0
α ray emission (count/cm^2h)	<0.001			
Underfilling method	CUF / VCUF			NCF

Opportunities in 3D Packaging Solution



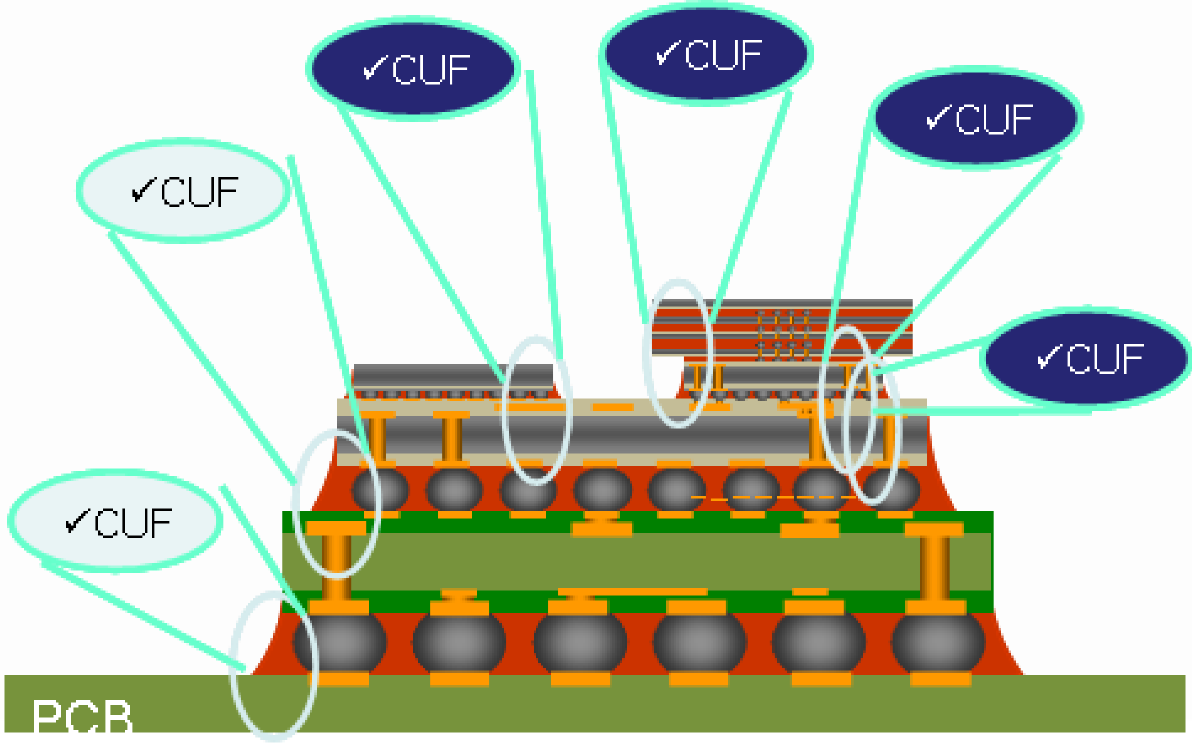
Epoxy Line-Up by Application Method

Type	Post-dispensing			Pre-applied					
	CUF (Capillary UnderFill)			**NCP** (Non Conductive Paste)		**B-stagable NUF** (No flow UnderFill)			**NCF** (Non-Conductive Film)
Application by	Dispensing			Dispensing		Dispensing		Spin	Lamination
	Air	Jet	Vacuum	Air	Jet	Air w/ special nozzle	Spray		
Apply to	Die attached substrate			Substrate		Substrate or Wafer		Wafer	Substrate or Wafer
Flux process	Required			Not required					
Die attachment process	Mass reflow or TCB			TCB (Thermal Compression Bonding)					

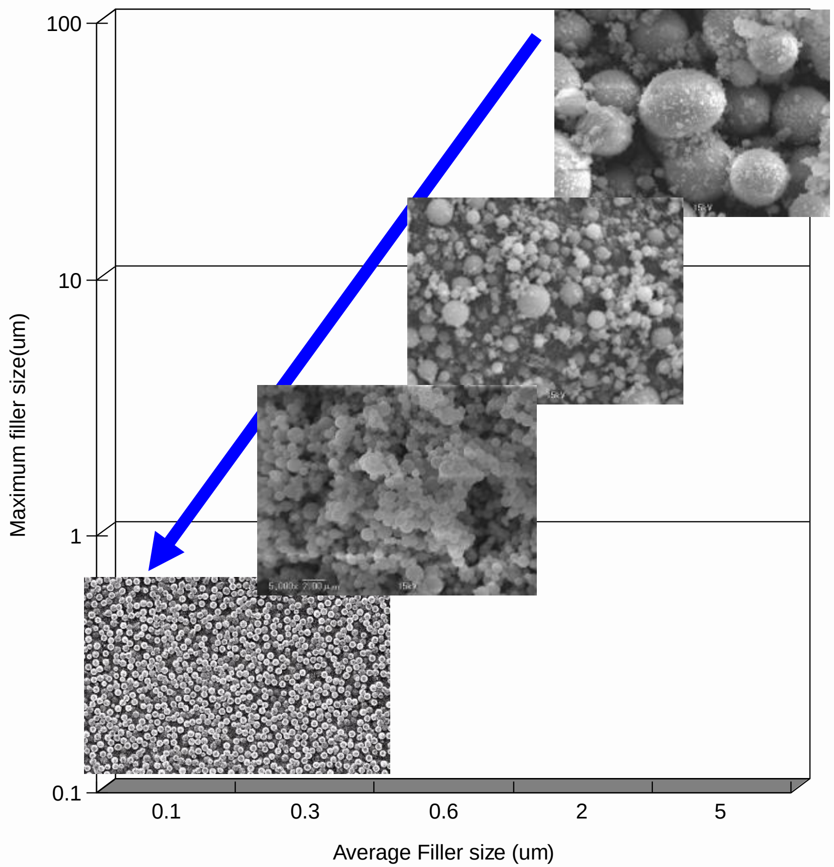
Capillary Underfill (CUF) for 3D Packaging

Key properties

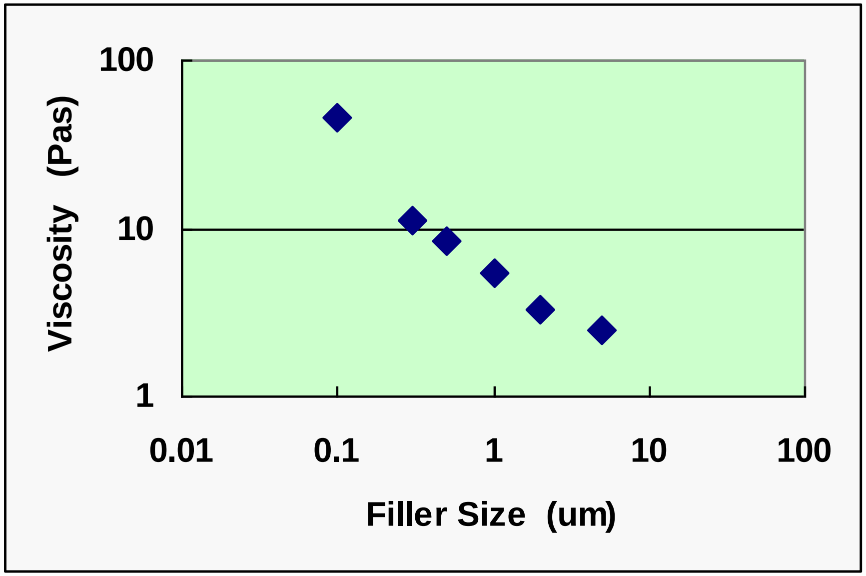
- *High Flow-ability for Narrow Gap*
- *High precision dispensing*
- *Vacuum assisted process*



Filler Design

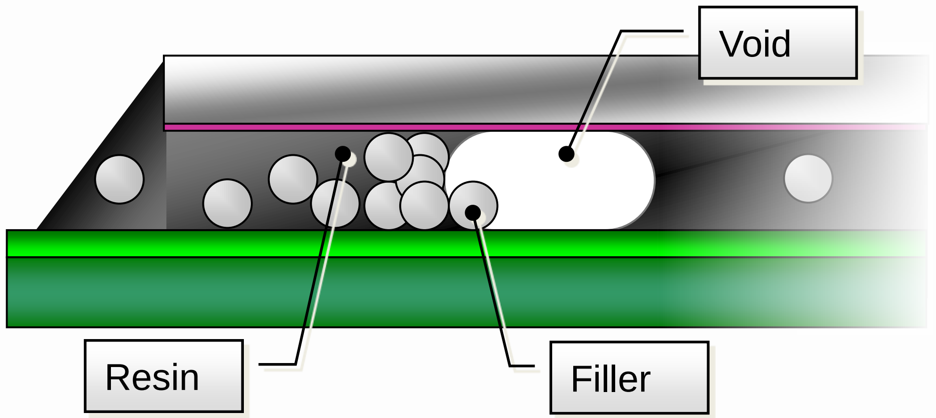


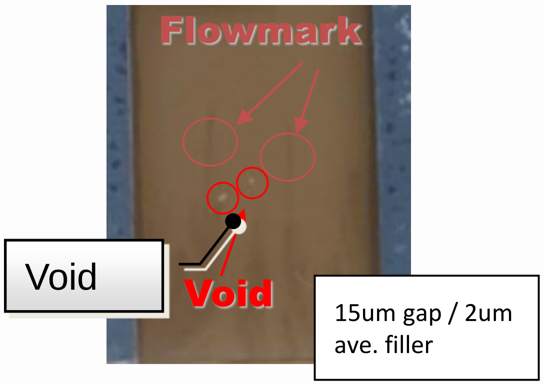
For fine pitch and narrow gap, filler size must be considered for good capillary flow.

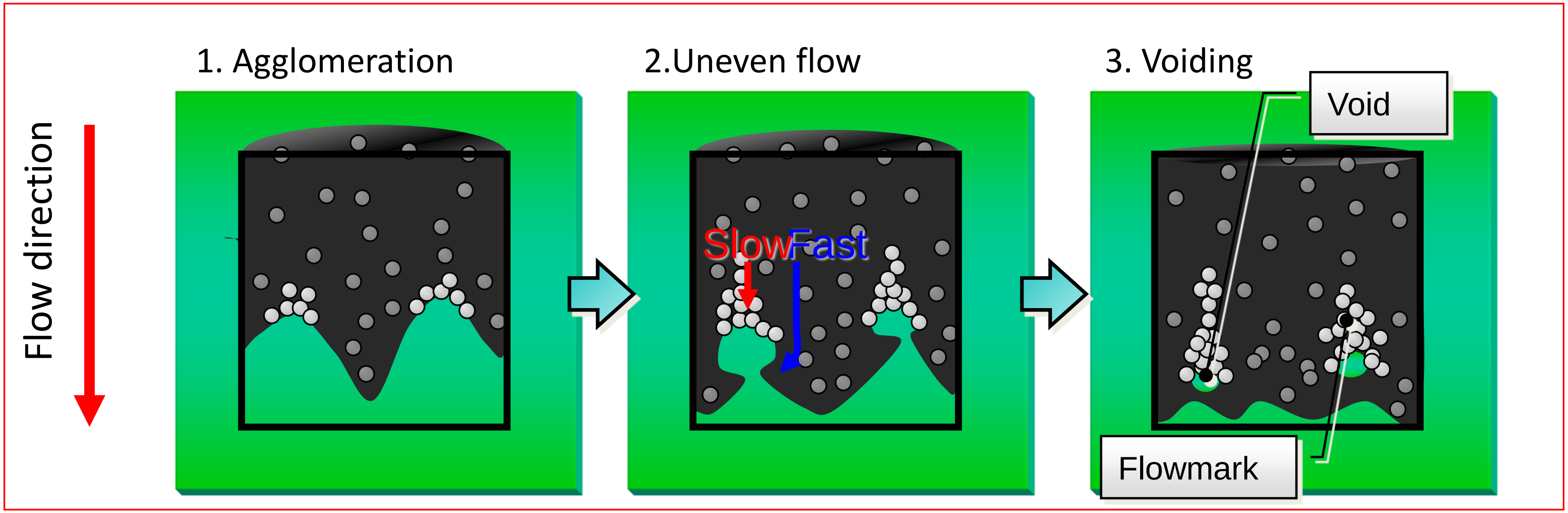


Its drawback is that fine filler significantly increase viscosity of underfill.

Root Cause for Voiding with Larger Size Filler



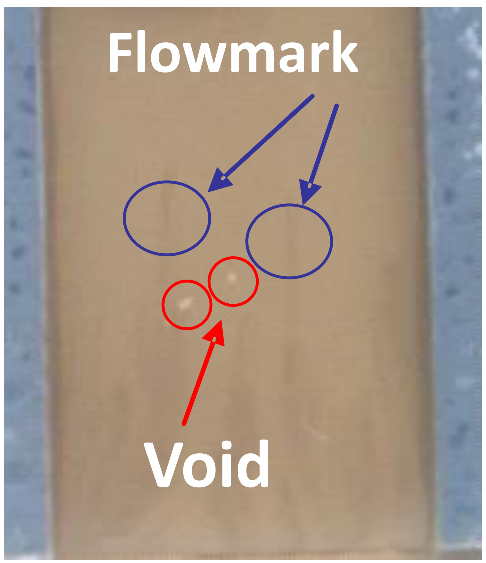




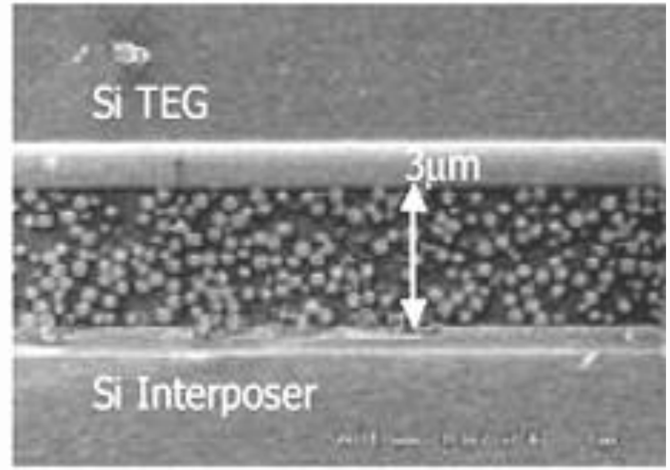
High Flowability for Narrow Gap

Flow comparison:

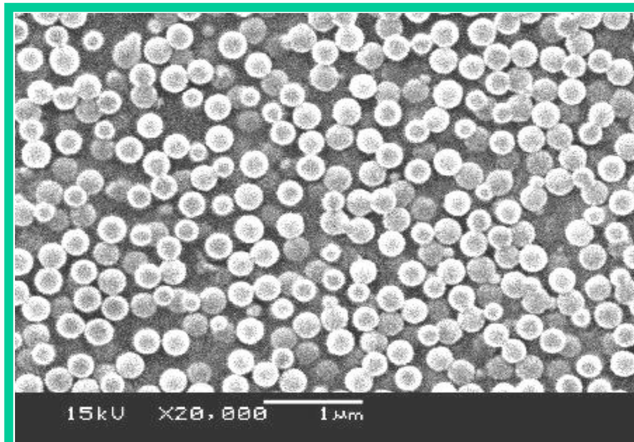
Filler size 2um ave.



Filler size 0.3um ave.



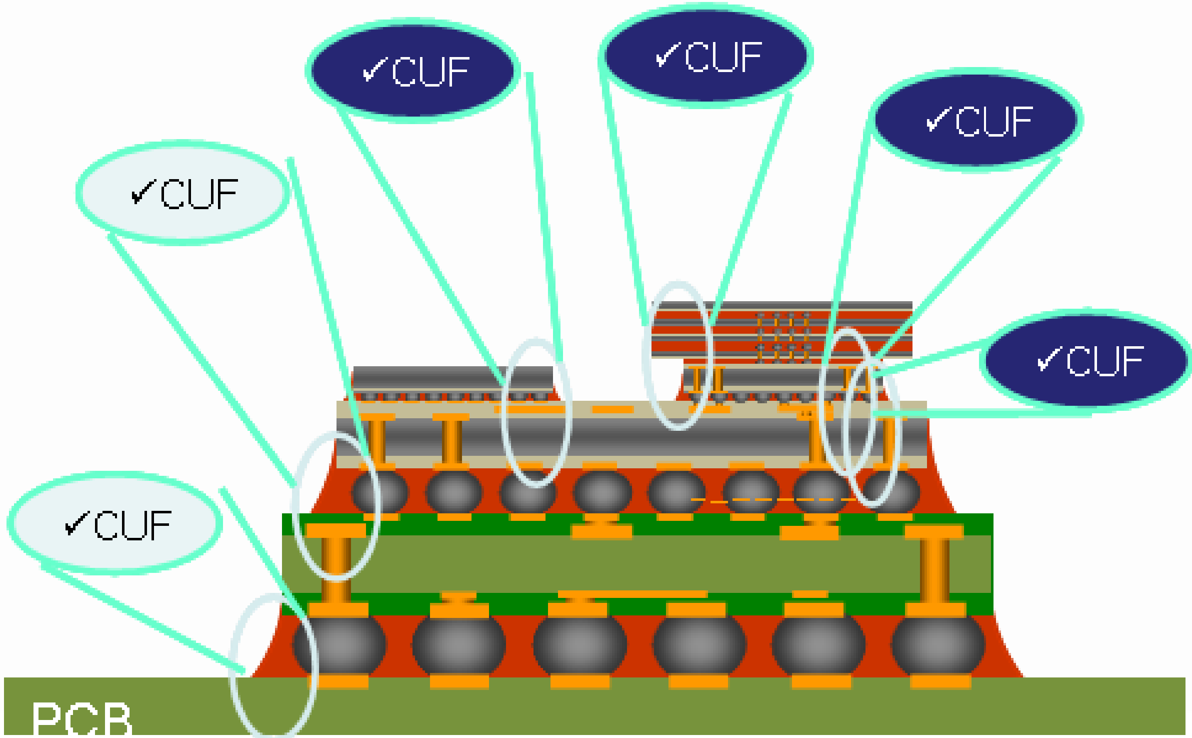
SEM Photo of cross section



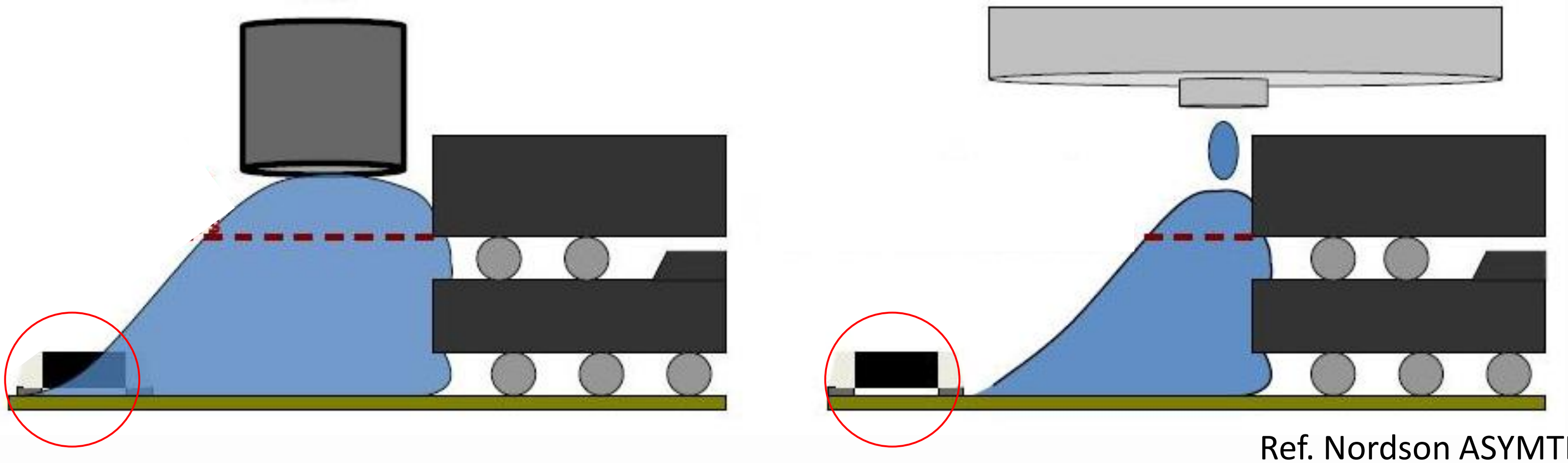
Capillary Underfill (CUF) for 3D Packaging

Key properties

- ★ *High Flow-ability for Narrow Gap*
- ☐ *High precision dispensing*
- ☐ *Vacuum assisted process*



Dispensing Method; Needle or Jet ?



Ref. Nordson ASYMTEK

Needle dispensing

✓Keep out zone (*KOZ*) is getting smaller.
✓No space for needle nozzle.

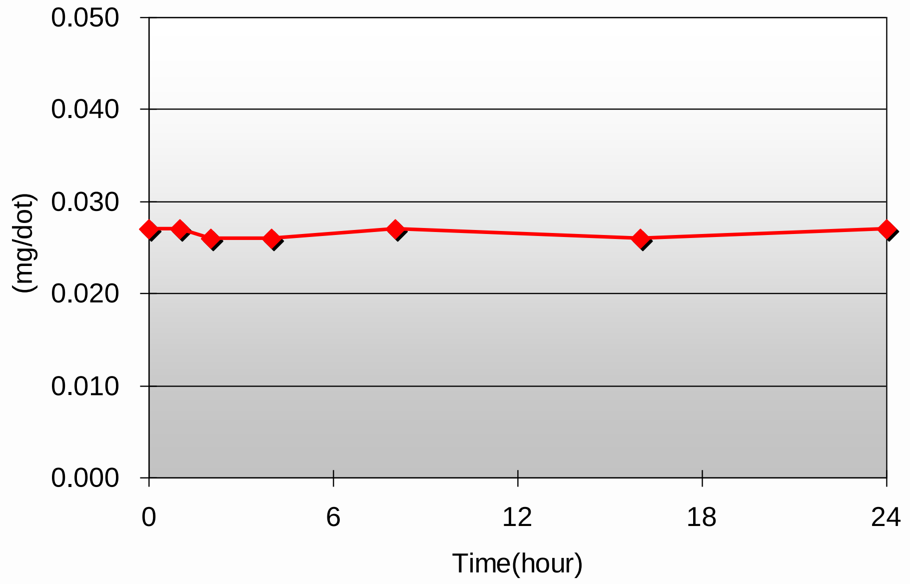
Jet dispensing

✓Jetting can maintain minimum KOZ with accuracy.
✓Requires less space than needle dispensing

High Repeatability Dispensing

Underfill material	Dispensed weight		
	0h	16h	24h
NAMICS	0.027mg/dot	0.026mg/dot	0.027mg/dot

Namics underfill shows stable performance with jet dispensers.



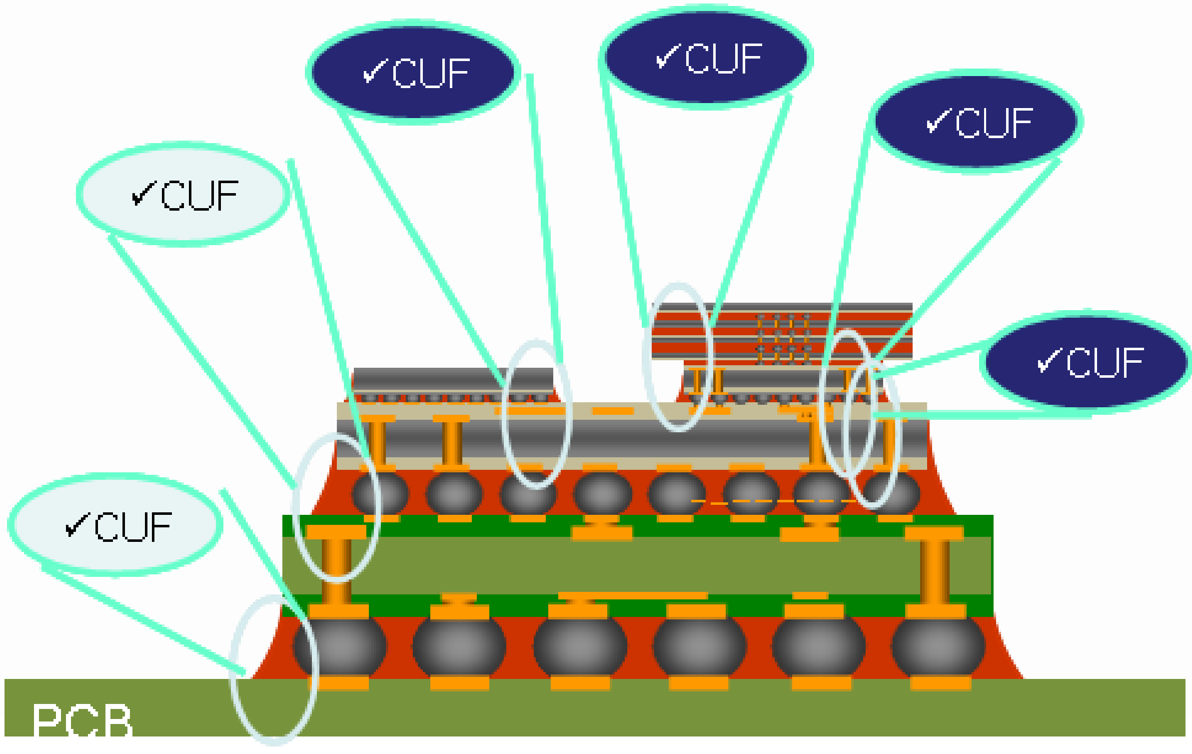
Conditions	
Instrument	Asymtek DJ9000 Jet Dispenser
Fluid pressure	0.02 MPa
Nozzle temperature	70 deg.C
Stage temperature	90 deg.C

Namics Underfill is designed for jet dispensing.

Capillary Underfill (CUF) for 3D Packaging

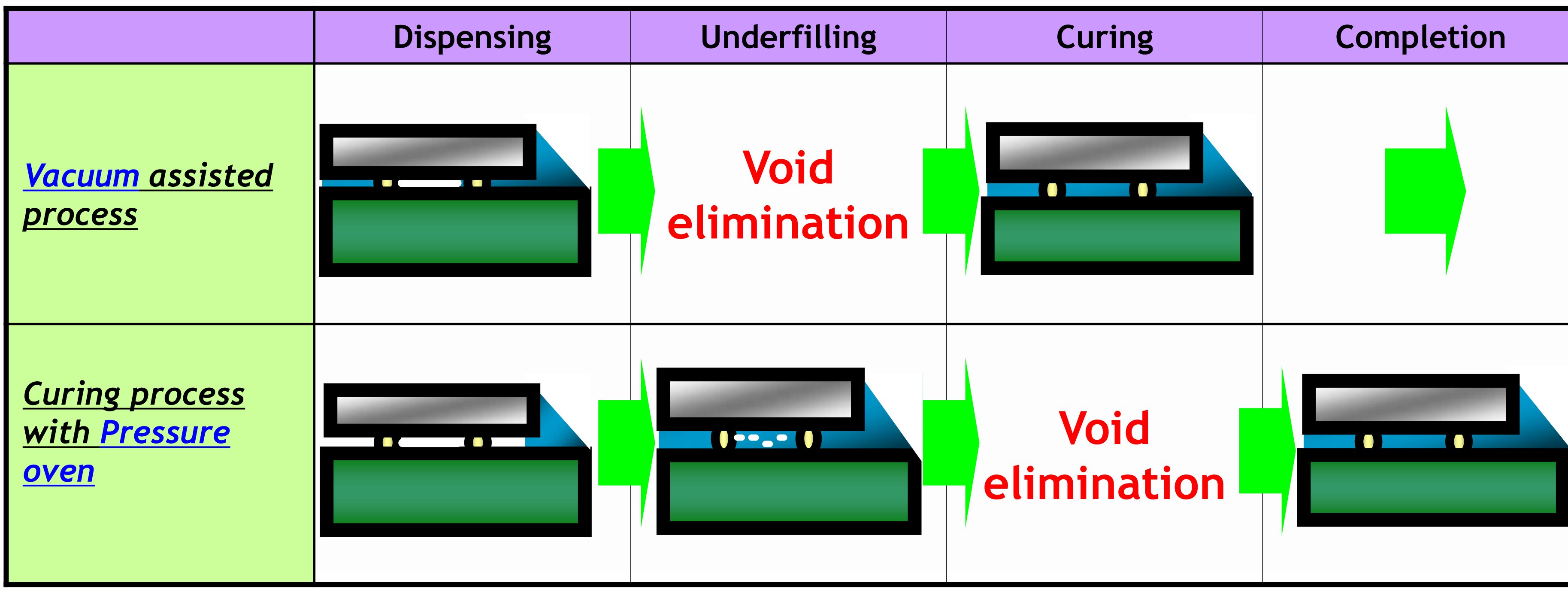
Key properties

- ★ High Flow-ability for Narrow Gap
- ★ High precision dispensing
- ☐ Vacuum assisted process



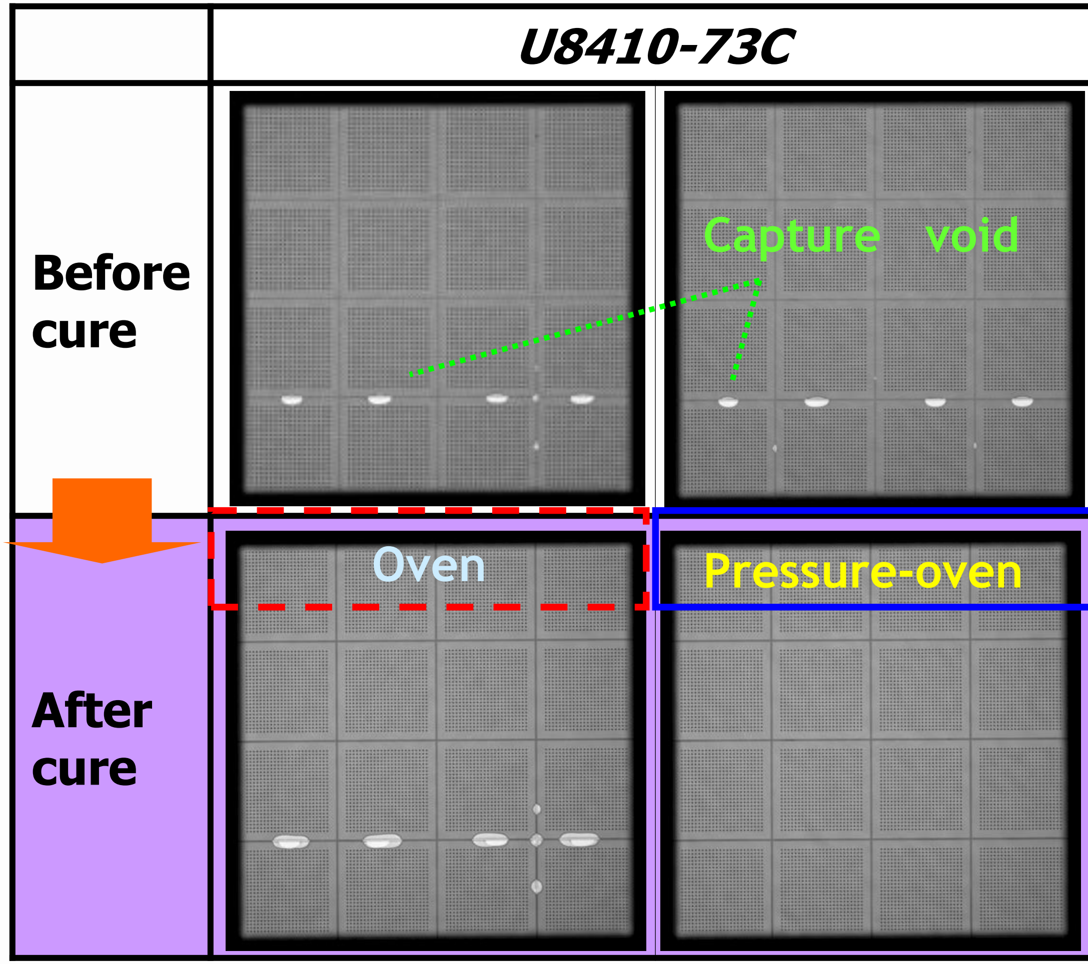
Void Elimination Process / Pressure Oven

	Vacuum assisted process	*Curing process with Pressure oven*
Equipment	Vacuum system	Pressure oven
Void reduction process	At underfilling	At curing
A sort of void to eliminate	Capture	Capture, Moisture
Size of void to eliminate	Large ~ Small	Small
Underfill	VCUF	CUF



Void Investigation w/Pressure-oven

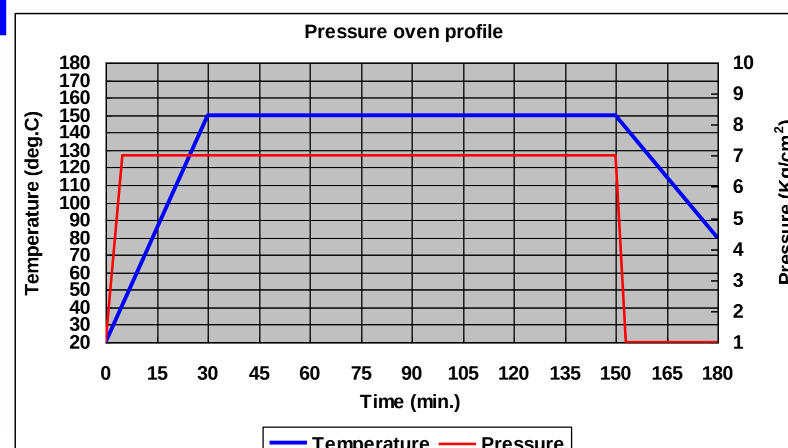
Capture void investigation



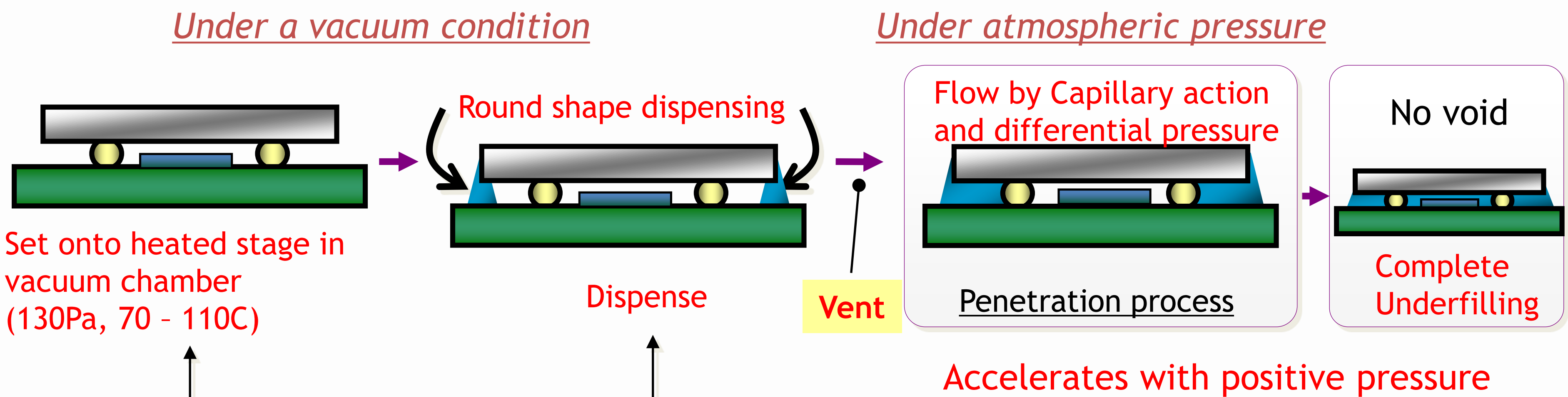
Voids remain. Voids disappear.

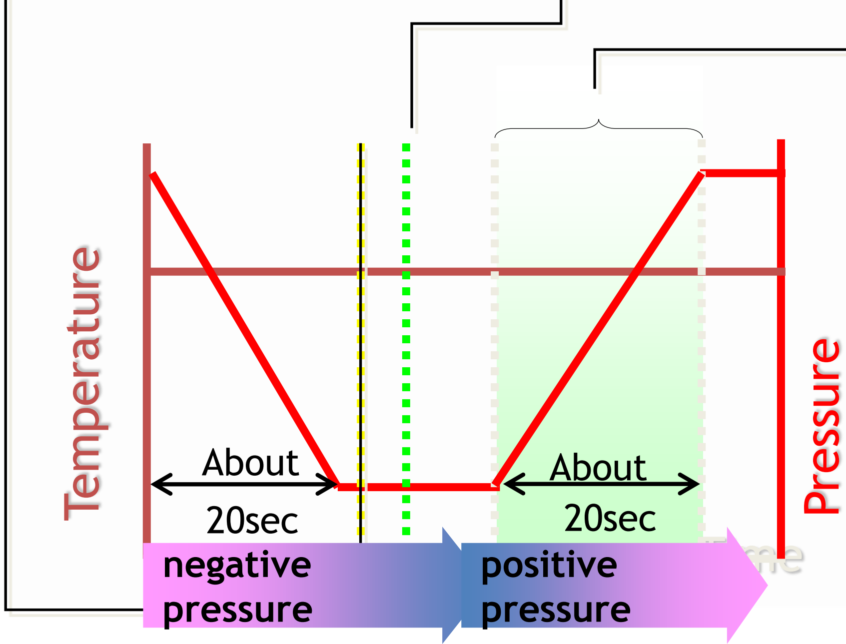
TEST vehicle
Die size : 20mmx20mmx0.73mm(t)
Passivation : PI
Bump material : Sn/3Ag/0.5Cu
Bump pitch : 175um
Flux : non-clean
Substrate size : 52.5mmx30.0mmx0.73mm(t)

UF	Pressure-oven Type	Pressure value
NAMICS	VFS-60A-JP	7 kg/cm^2

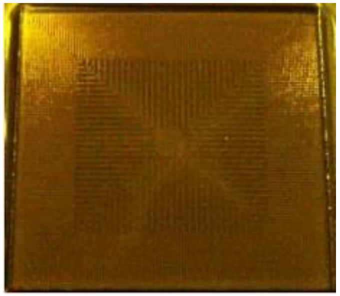


Void Elimination Process / Vacuum Assisted

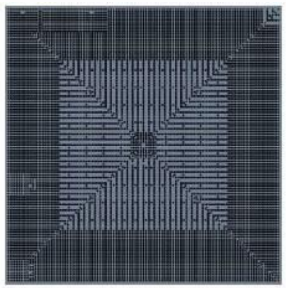




Microscope View



C-SAM View

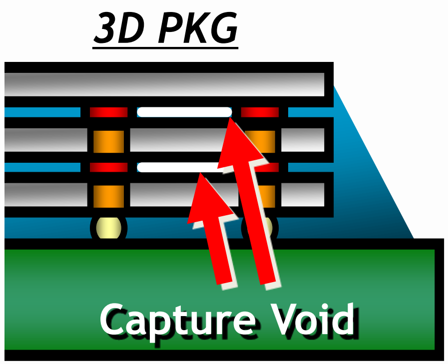


IBM test vehicle
19 x 19mm die
150um pitch, Pb free C4

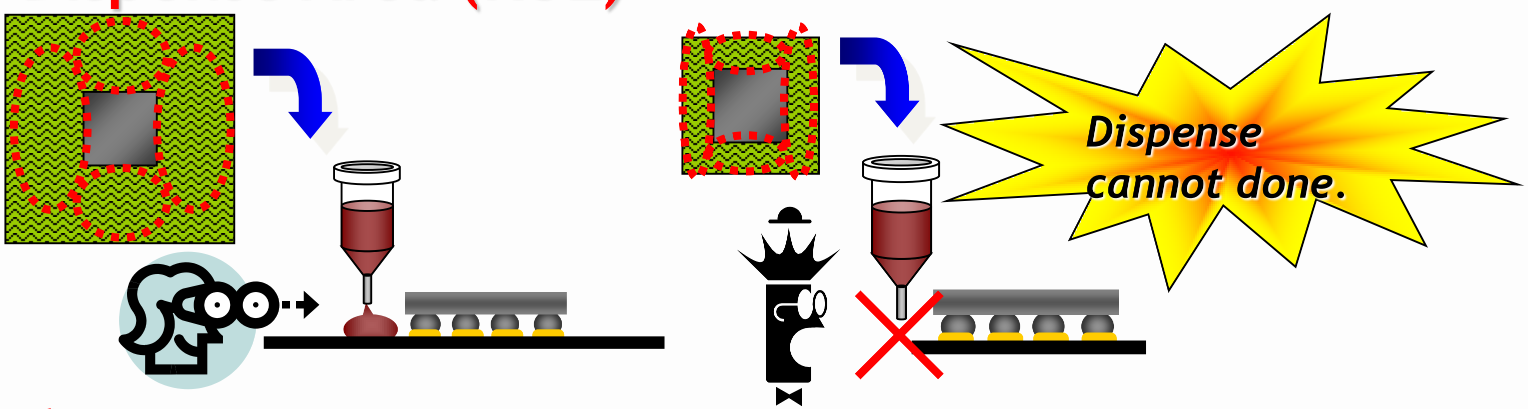
Ref. Horibe, ECTC2011

Problems for CUF & Advanced PKG

*Void Issues

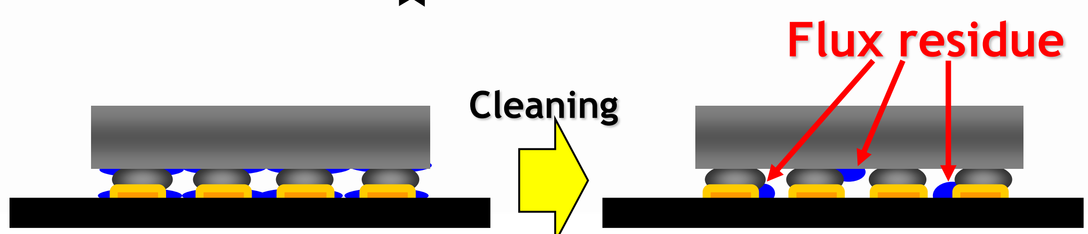


*Decrease Dispense Area (KOZ)



*Flux Residue Issue

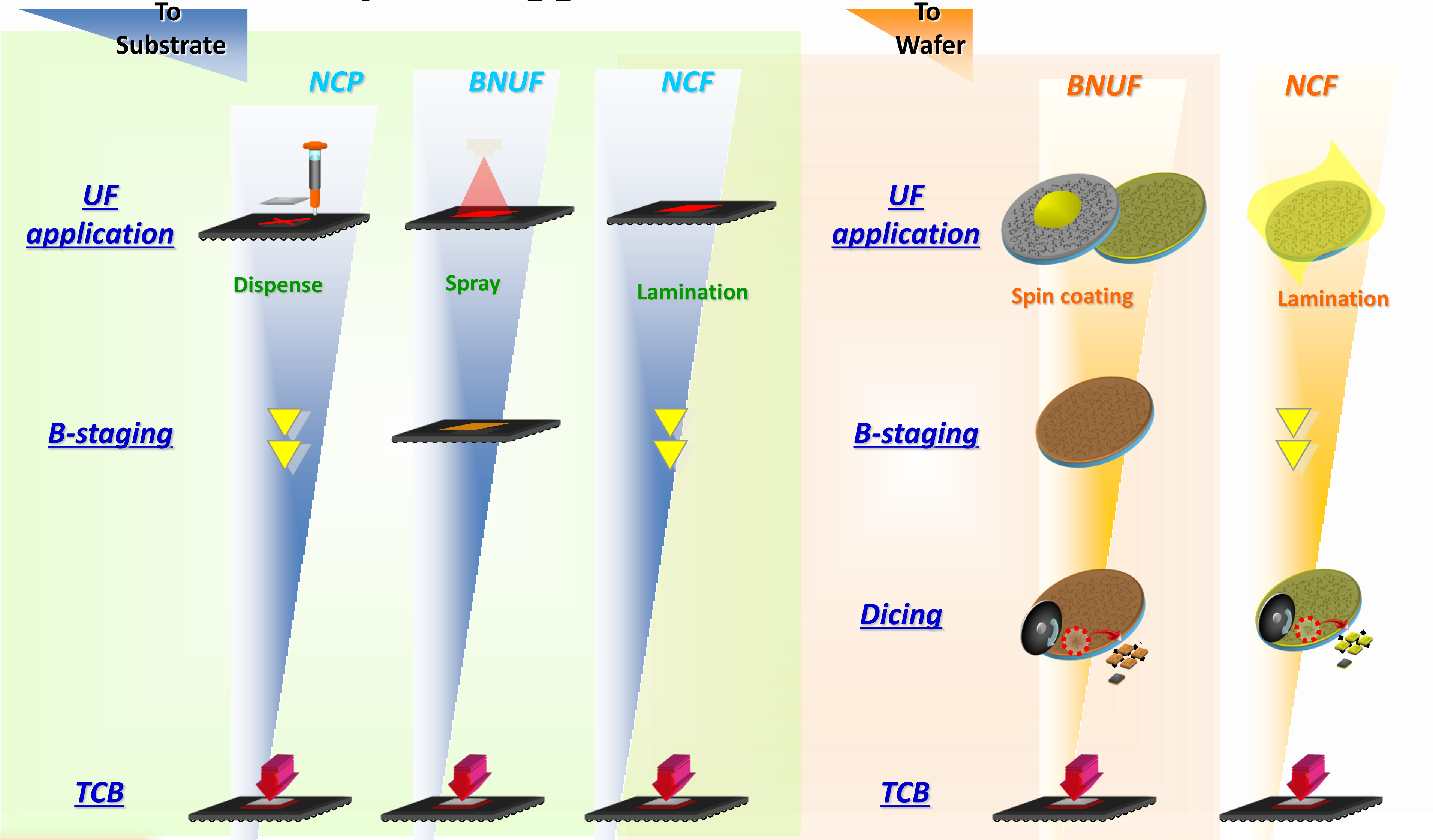
Difficult for the package
of a narrow gap to Clean flux.



New Materials For 3D Packaging

Material	Non Conductive Paste (NCP)	Non Conductive Film (NCF)	B-Stage No Flow UF (BNUF)
Features	*Flux free process -> No flux cleaning required*		
	No mass reflow process -> Low stress to Low-K layer		
	Excellent penetration for narrow gap & pitch		
	Minimum fillet forming for small KOZ (limited spaces around die)		
	Low strain at bumps can be achieved since bumping connection and NCP curing are done simultaneously while NCP is reinforcing bumps.		
	•*Can be used current dispensing machines* •*Will fit package shape*	*Fine thickness control while providing minimum fillet width; in addition, no risk of underfill creeping on to die.*	*Excellent penetration into uneven surface and very fine areas because of its low viscosity*

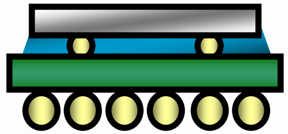
Introduction of Pre-Applied Materials



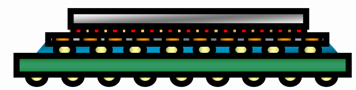
Target Package for Each PAM

Apply to	*Apply to*	*Application pattern*	*TCB pattern*	*Package*	*Application method*	Encapsulation method: NCP	NCF	BNUF
Bottom die	Substrate or Interposer		D2S: Die / Substrate	FCBGA FCCSP	Dispensing	✓		
					lamination		✓	
					Spray			✓
		or	D2D: Die / Interposer or Die	2.5D 3D	Dispensing	✓		
					Lamination		✓	
					Spray			✓
	Interposer		D2W		Photoliso		✓	
					Spray			✓
					Printing			✓
Upper die	Wefer		D2D: Die / Interposer or Die; D2W	FCBGA FCCSP 2.5D 3D	Lamination		✓	
					Spin and spray			✓
					Spin on			✓

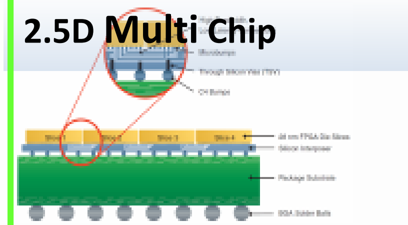
FCCSP



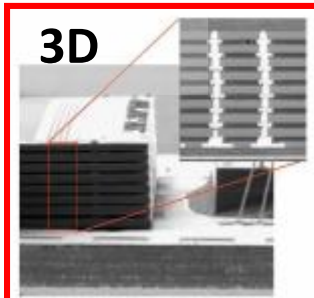
2.5D Single Chip



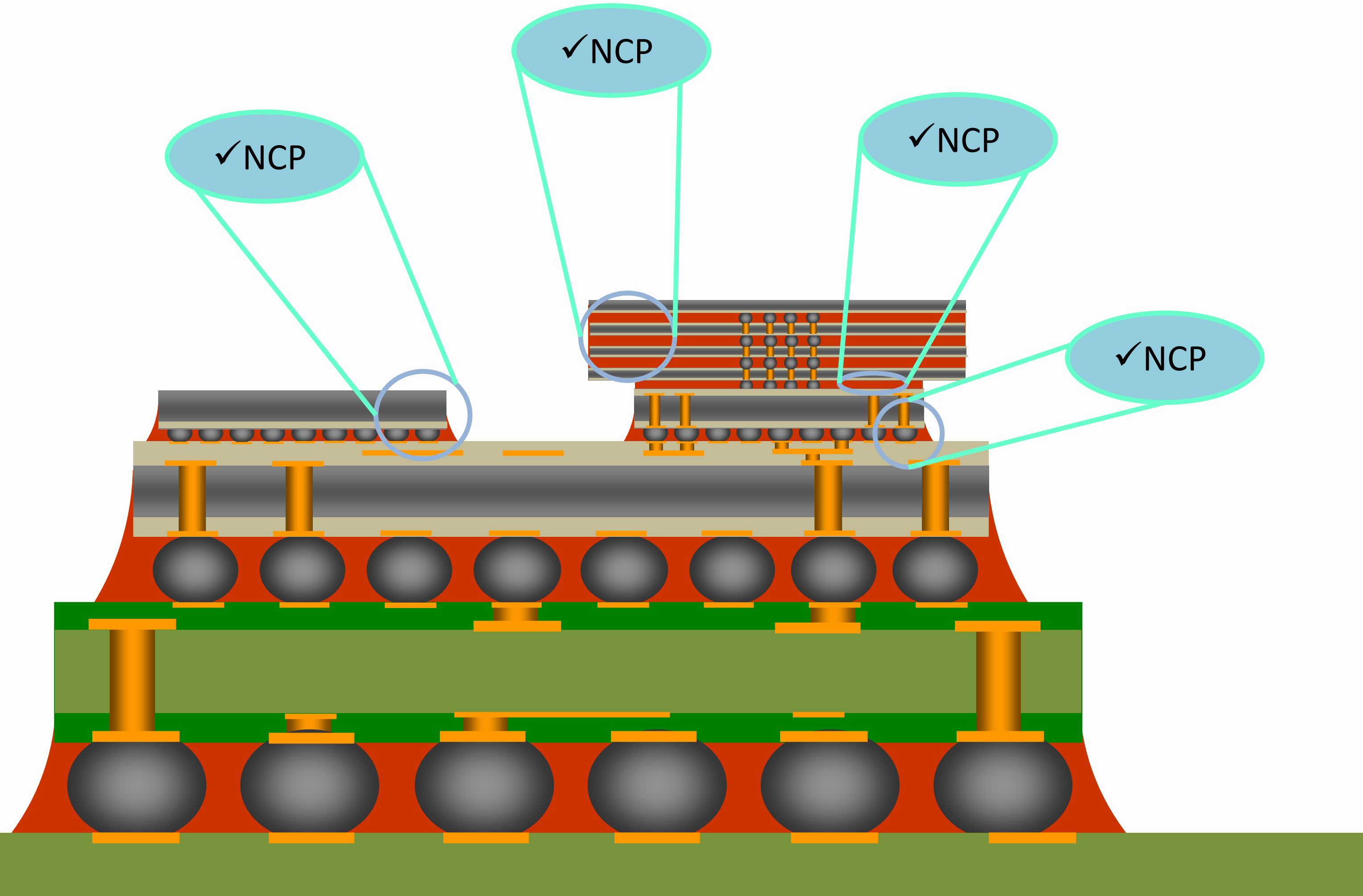
2.5D Multi Chip



3D

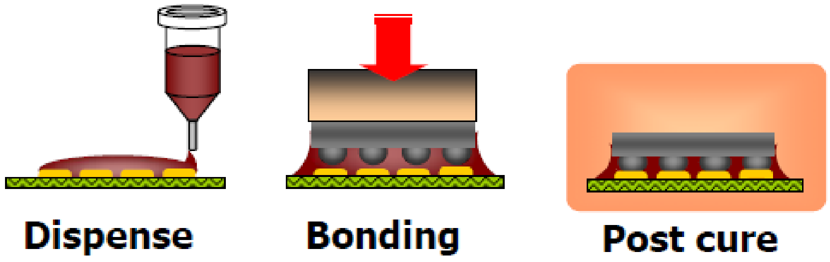


Non-Conductive Paste (NCP) for 3D Packaging

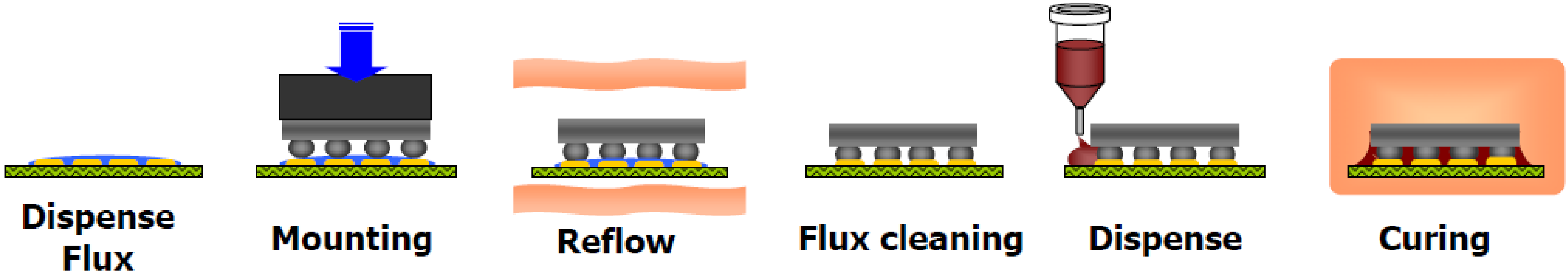


Non-Conductive Paste (NCP) Process Flow

NCP



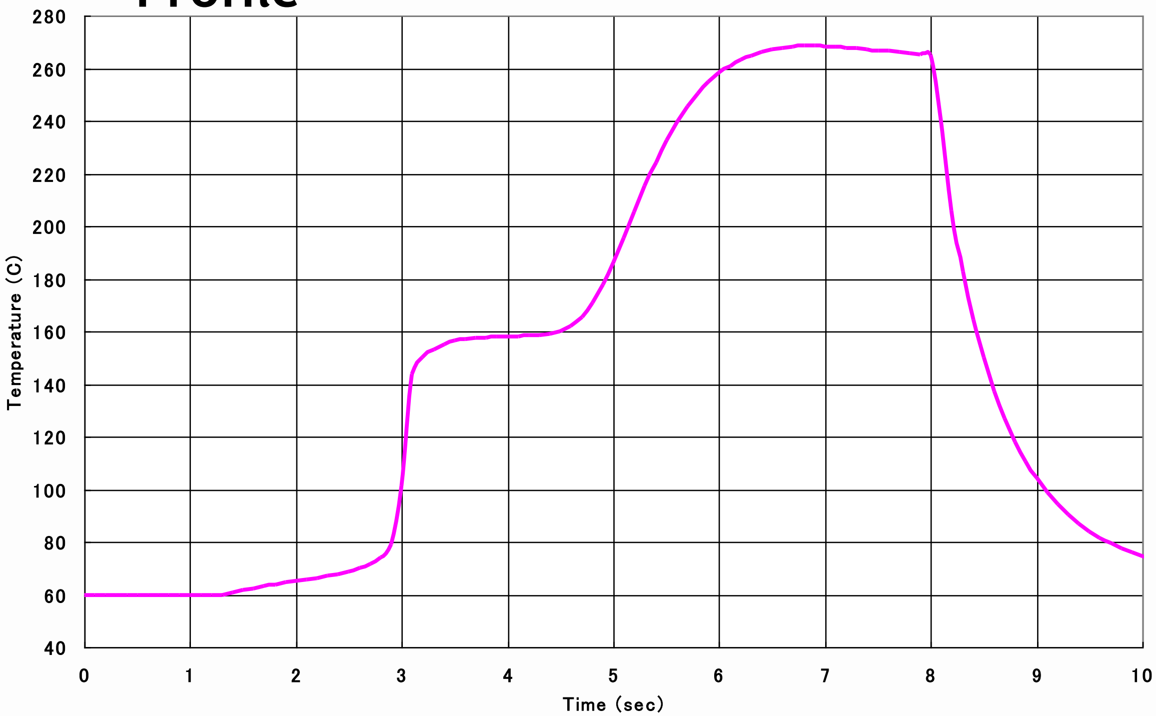
capillary flow type (CUF)



What is NCP? A self fluxing low cte material that can be used in conjunction with thermal compression bonding.

TCB & Test Vehicle Condition

*Profile



Equipment : FC3000S (Toray Engineering)

Stage temp. : 60C

Search height : 0.6 mm

Search speed : 0.6mm/sec

Contact force : 5.4N

Max. force : 24.5N

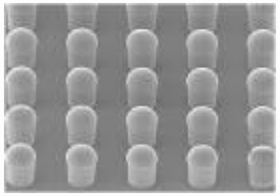
*Test vehicle

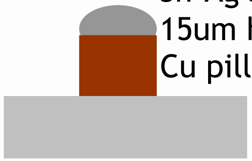
- Die size : 7.3mmX7.3mmX0.125mm(t)
- Bump structure : Cu pillar with solder (solder / Pillar = 15um/30um)
- Number of bump : 544
- Bump layout : Peripheral
- Sub. thickness : 0.36mm
- Lead finish : Cu/OSP (ENTEK)

Reliability Test Results

Chip

Material		Si
Size		7.3mm x 7.3mm
Thickness		125 um
Bump	Substance	Cu pillar w/ Sn-Ag solder
	Alignment	Peripheral
	Pitch	50 um
	# of bumps	544



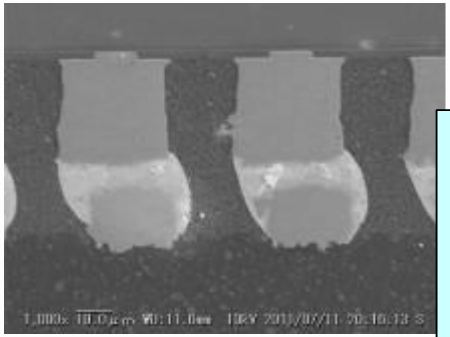


Substrate

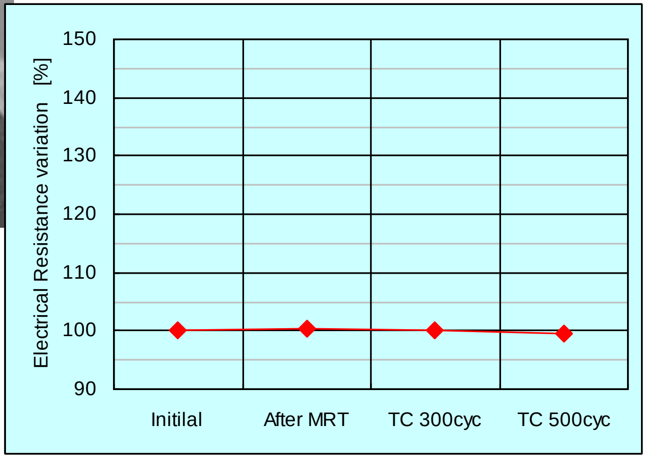
Substrate material	Organic substrate
Thickness	360 um
Electrode material	Cu/Sn-Ag solder

C-SAM

Cross-section at Initial

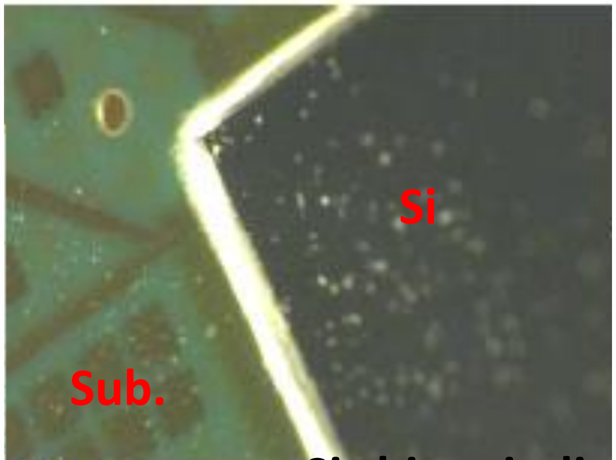


Electrical Resistance

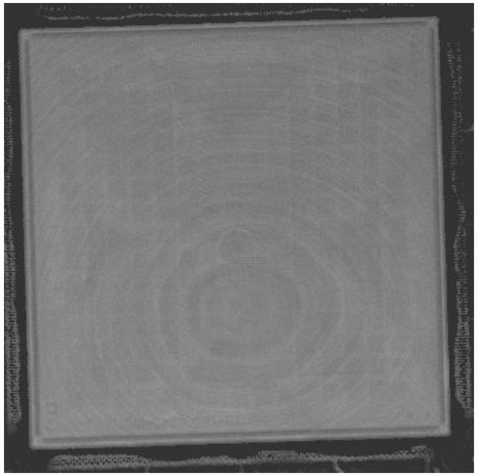


Result

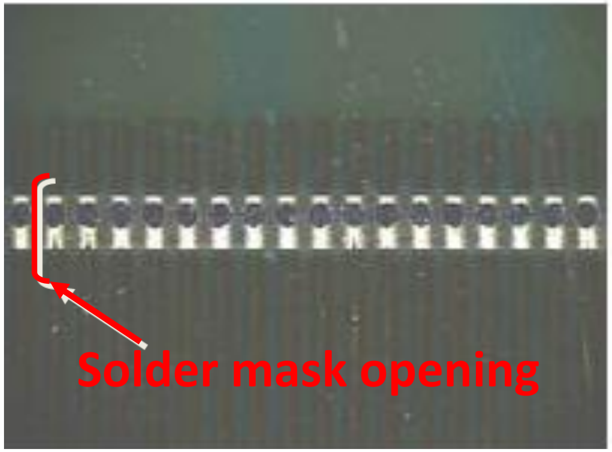
Fillet view



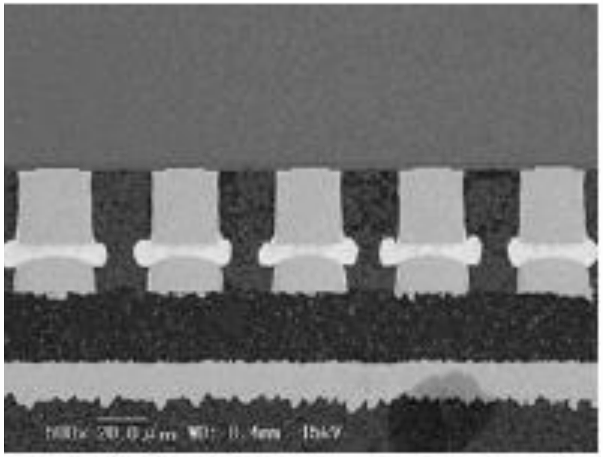
SAT view



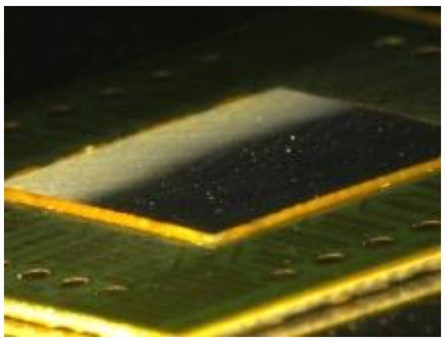
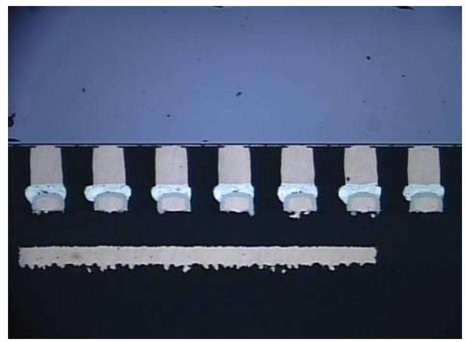
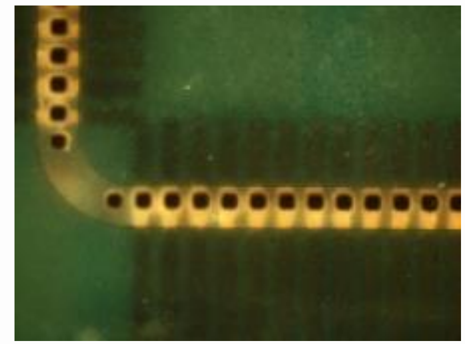
Si chip grinding view

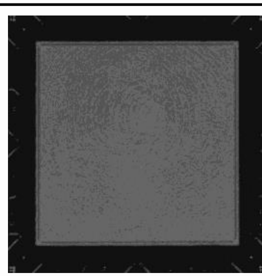
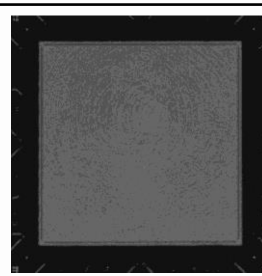
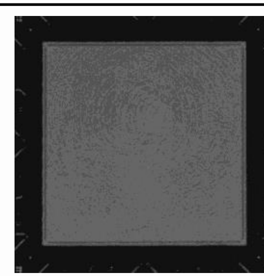
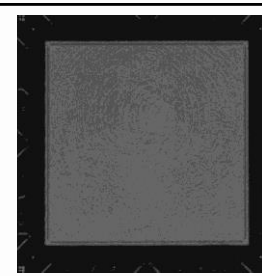
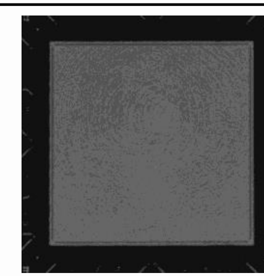


X-section view



Reliability Evaluation Results

Appearance	Connection	Void (solder resist opening)
		

	After cure	Reflow	Thermal cycle		
			100 cyc	500 cyc	1000 cyc
C-SAM					

Reflow test = 30deg.C/60%RH 192hrs , 260deg.C reflow X 3times
Thermal cycle test = -55deg.C/125deg.C

Thermal Compression w/ Capillary Flow (TCCUF)

TCCUF, which is abbreviation for "***Thermal Compression with Capillary Underfill***" is a hybrid fabrication method that used Capillary Underfill and a Thermal Compression Bonding process. The aim of this process is not only to keep assembly cost down, but also to ensure yield is not affected by filler entrapment or voiding with Non-Conductive Paste.

TCCUF, compared with other processes, is very simple. The hybrid process did not require a pre-baked, water clean, and flux residue removal. Thus, not only it is simplified process, but also saved total process time & increased yield.

Process Comparison

- Conventional underfill process

Fluxing dipping → Chip placement → Solder reflow → Flux Cleansing → Pre-baking → Plasma cleansing → Underfill dispensing → Underfill post-cure

- Thermal compression with nonconductive paste (TCNCP)

Plasma treatment → NCP dispensing → TC bonding → NCP post-cure

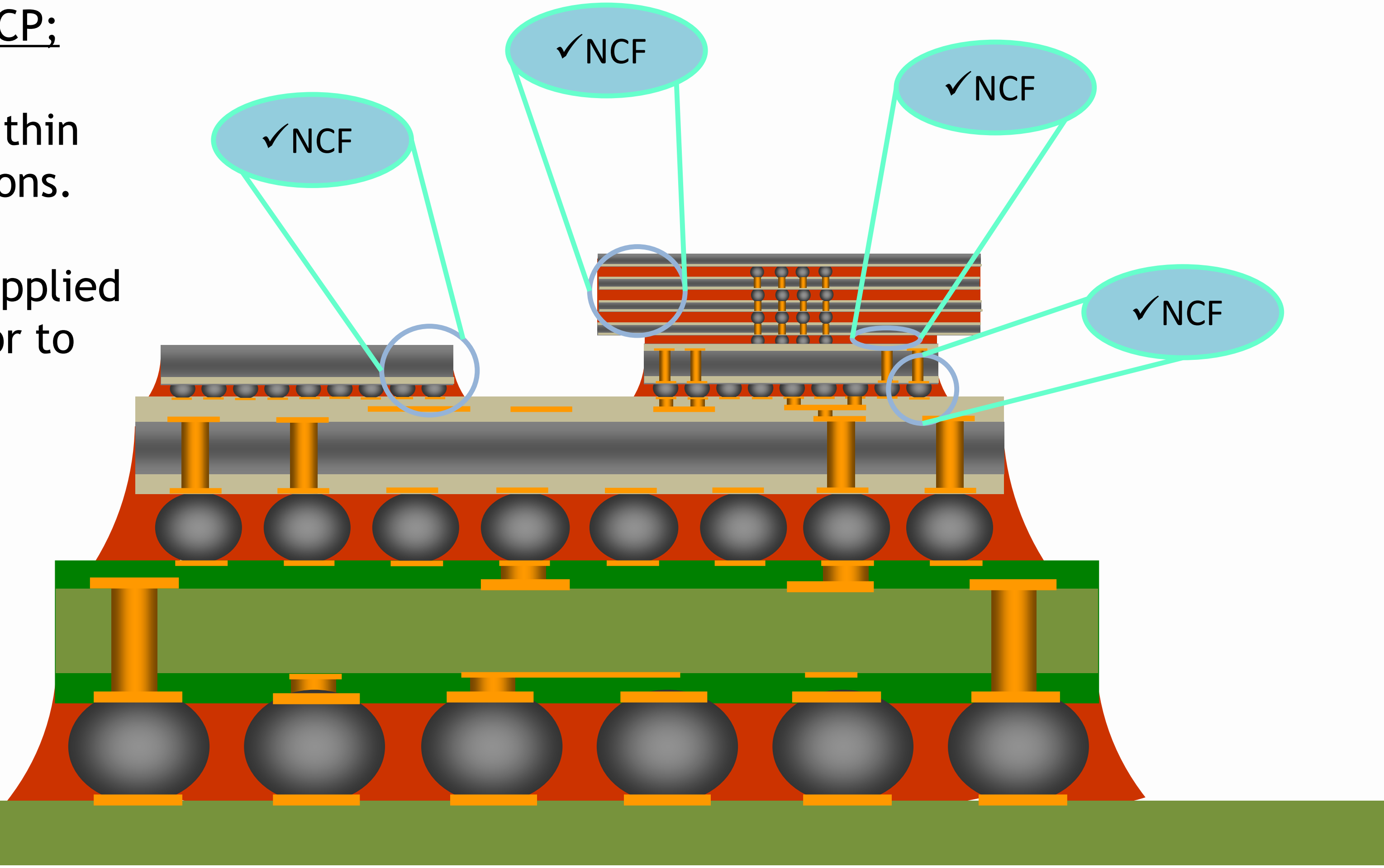
- Thermal compression reflow with capillary underfill process (TCCUF)

Plasma treatment → TC bonding → Underfill dispensing → Underfill post-cure with void removal

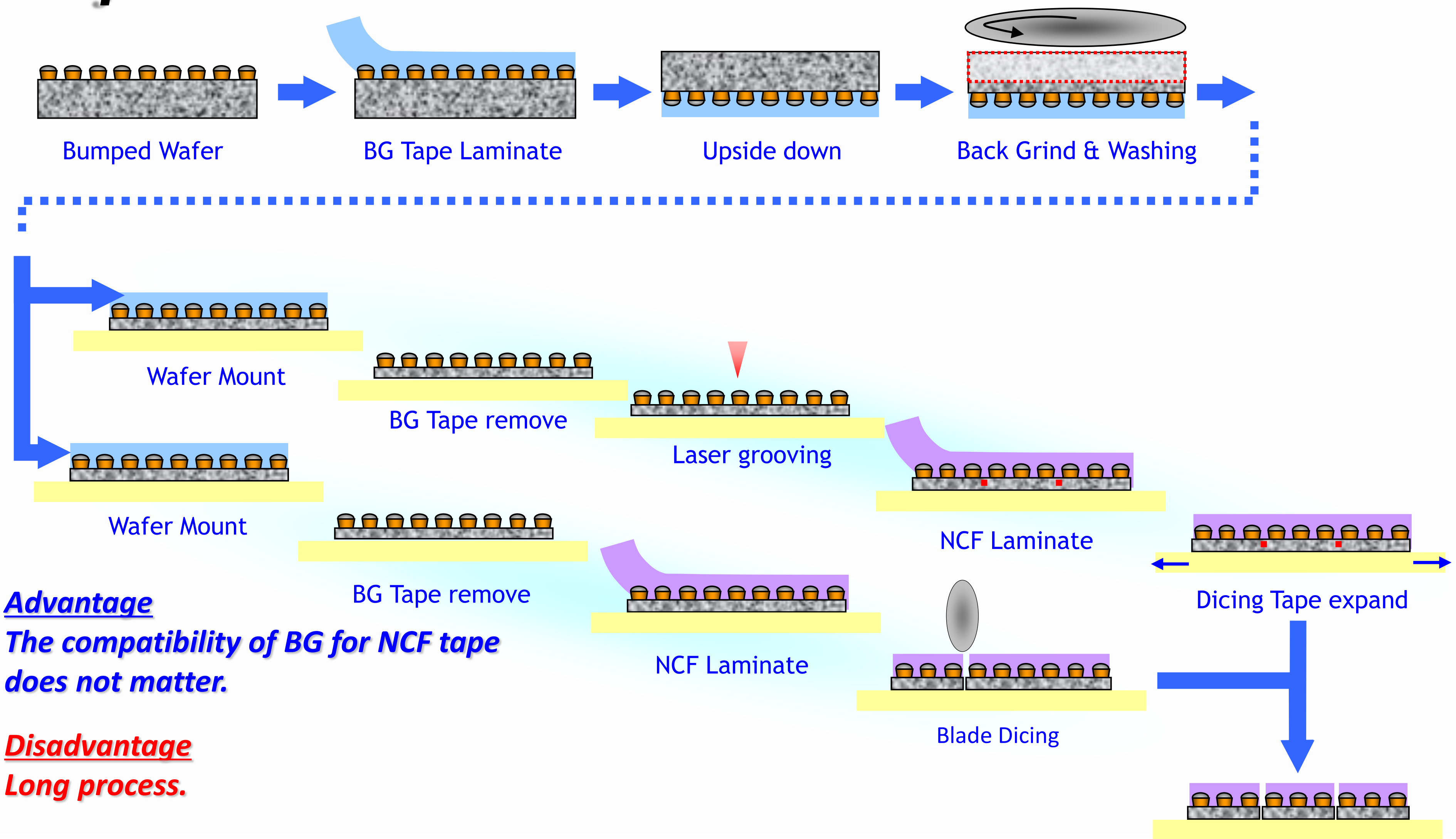
Non-Conductive Film (NCF) for 3D Packaging

Benefits over NCP;

- Essential for thin die applications.
- Can be pre-applied to wafer prior to dice.



Wafer Level Process



Advantage

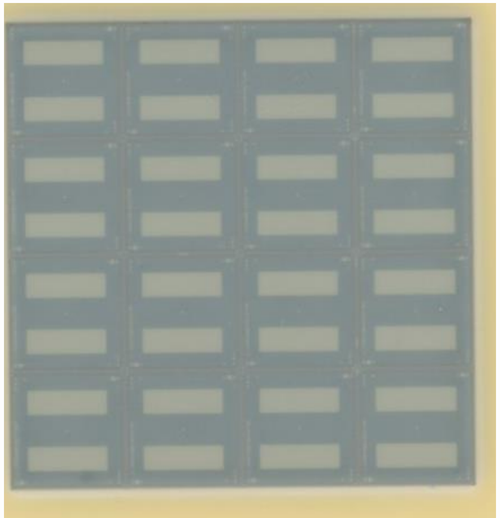
The compatibility of BG for NCF tape does not matter.

Disadvantage

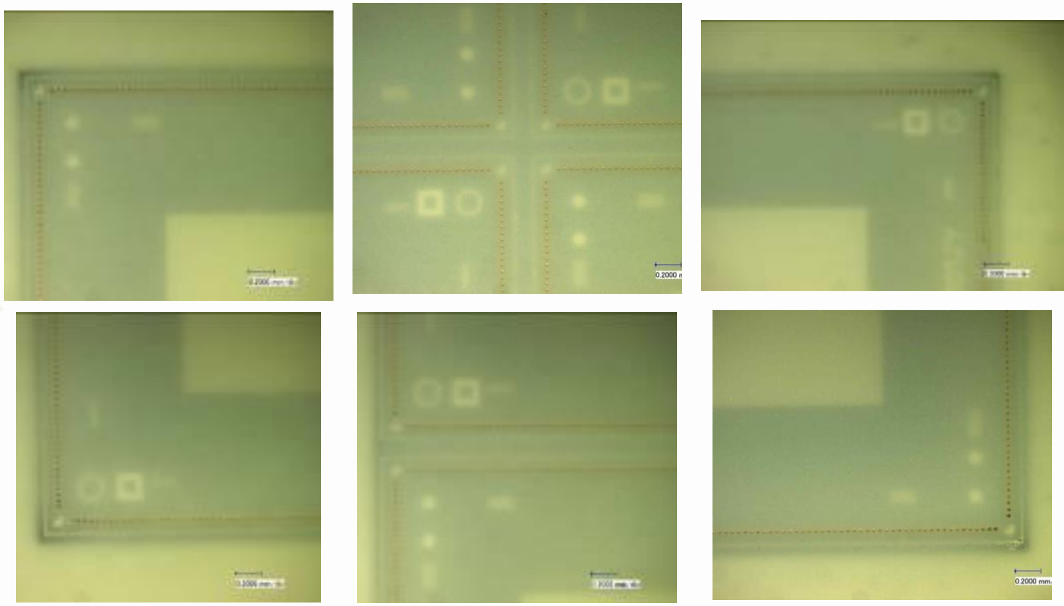
Long process.

Lamination Capability

Test peace after lamination

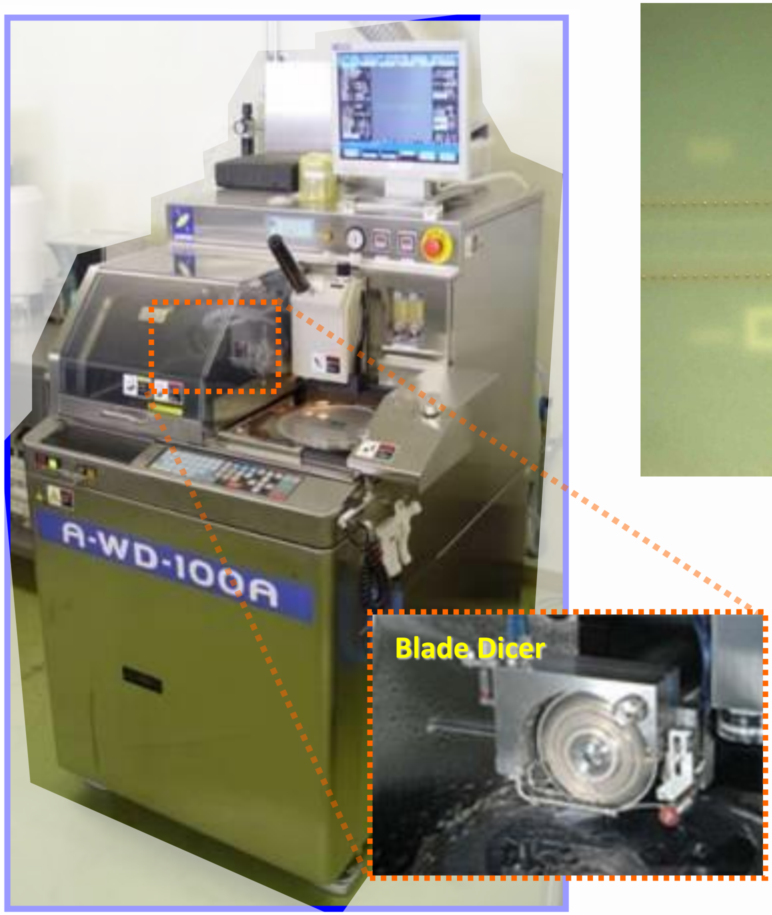


Observation

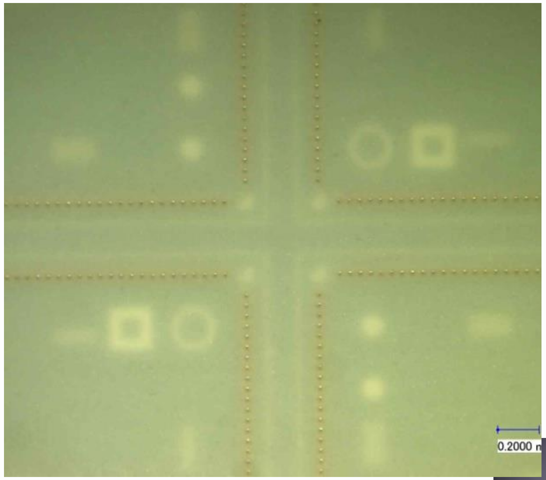


Good lamination capability has been confirmed.

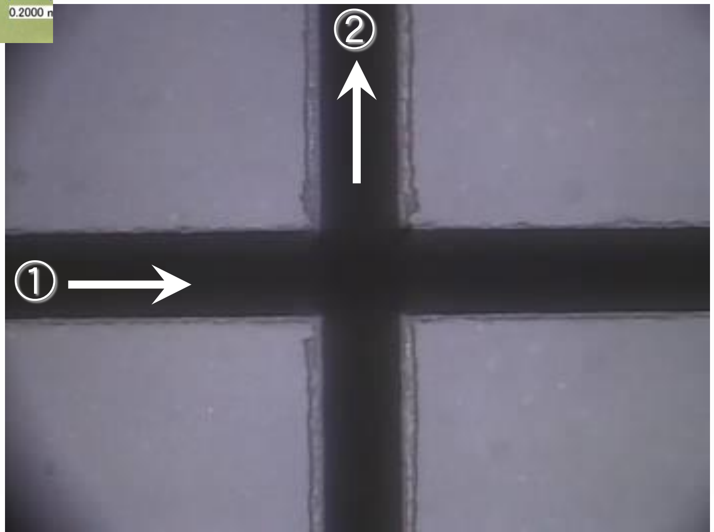
Dicing Capability



After Lamination



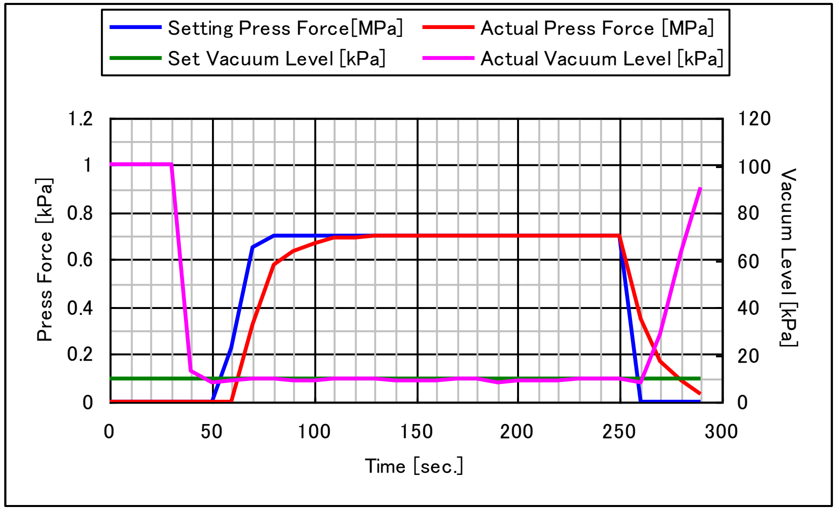
After Dicing



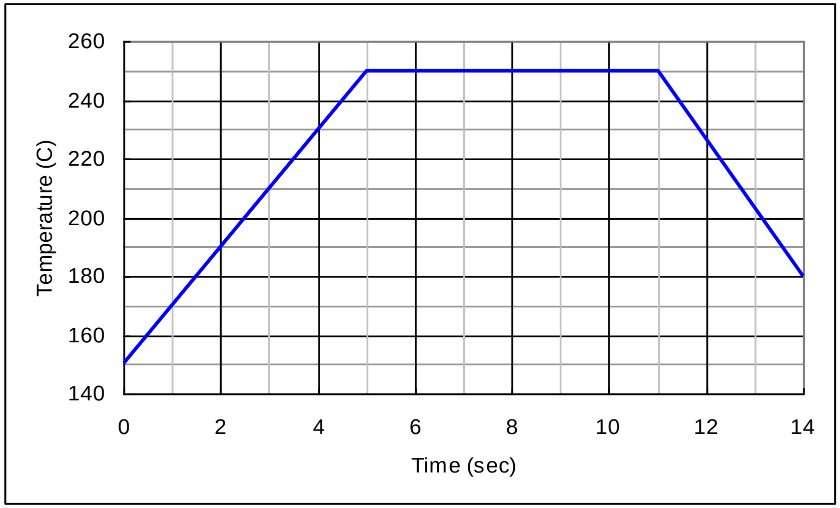
Process Condition for NCF

Step	Item	Condition
Baking Substrate	Temperature	125 deg.C
	Time	3 hours
	Equipment	Hot Air Oven
Film Laminate	Tmeperature	70 - 80 deg.C
	Press Force	0.3 - 0.7MPa
	Press Time	0.5 - 3 min.
	Vacuum Level	< 10kPa
Bonding	Stage Temperature	80 deg.C
	Bonding Force	0.3 - 0.6 N/mm2 (3 - 6 g/bump)
	Profile	Refer to the chart
Curing	Temperature	165 deg.C
	Time	1 hours
	Equipment	Hot Air Oven

Laminate Condition Example



Bonding Profile

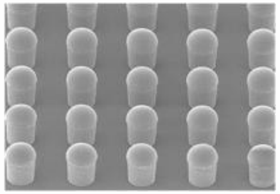


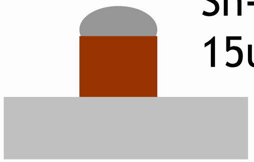
Profile is actual temperature between Chip and Substrate.

NCF Reliability Evaluation Results

Chip

Material		Si
Size		7.3mm x 7.3mm
Thickness		125 um
Bump	Substance	Cu pillar w/ Sn-Ag solder
	Alignment	Peripheral
	Pitch	50 um
	# of bumps	544





Sn-Ag solder
15um height

Cu pillar 30um height

Substrate

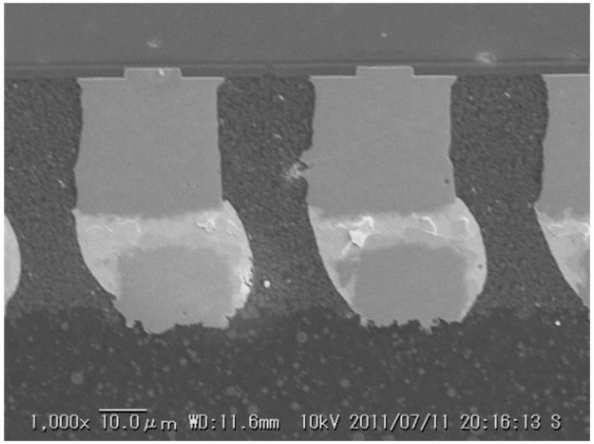
Substrate material	Organic substrate
Thickness	360 um
Electrode material	Cu/Sn-Ag solder

Reliability Test Condition
MSL Lv3. (60 deg.C/60%RH/ 40hr.) ▫260 dig.C Reflow/ 3times

Initial

After MRT

Cross-section



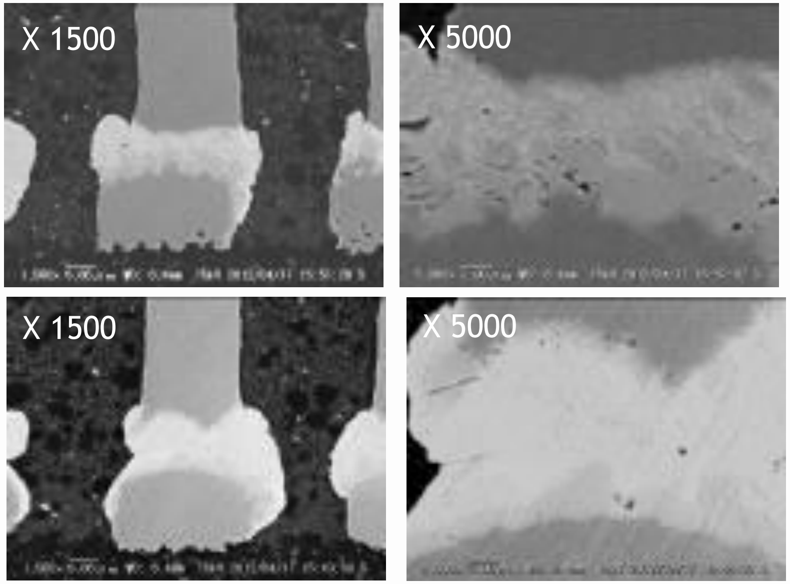
TCB

Substrate

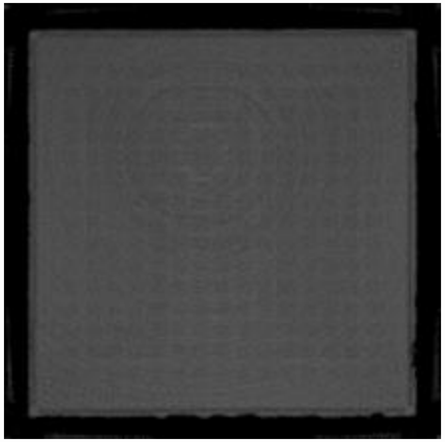
Substrate material	Organic substrate
Thickness	360 um
Electrode material	Cu/Sn-Ag solder

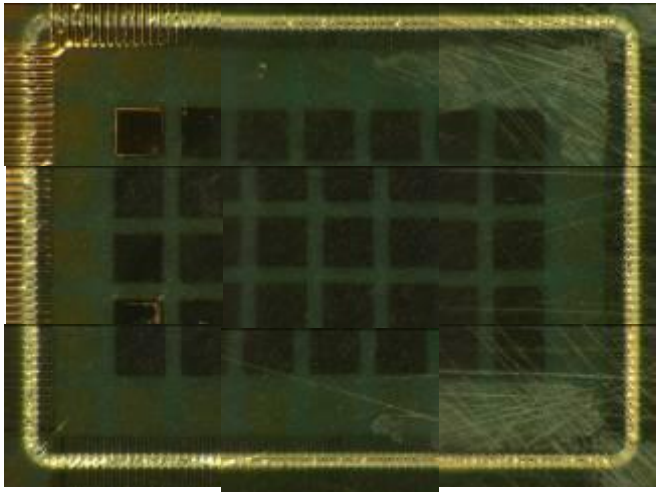
Good connection by solder melting was formed.
It was conformed no void.

Interconnection

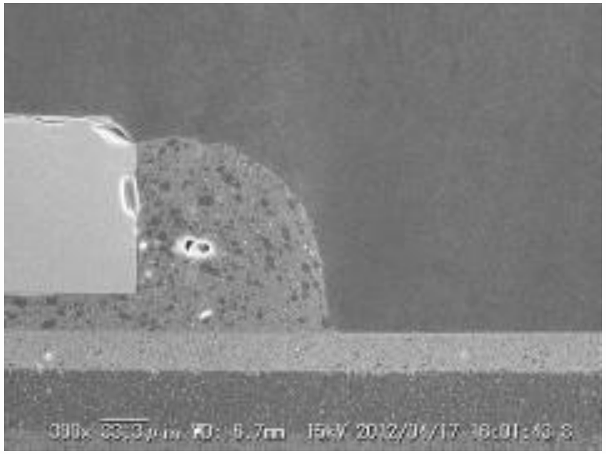


Void observation by C-SAM and Surface Grinding

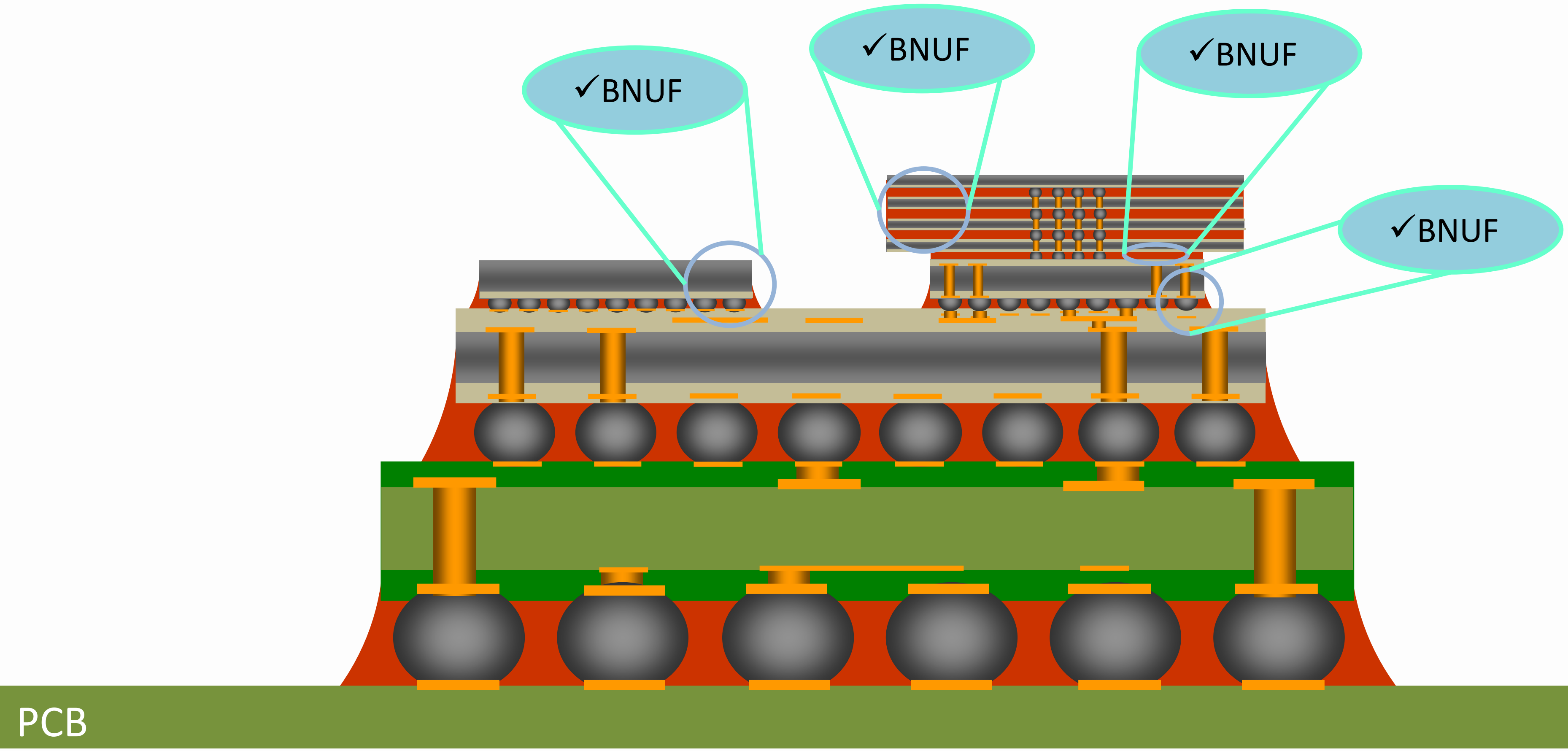




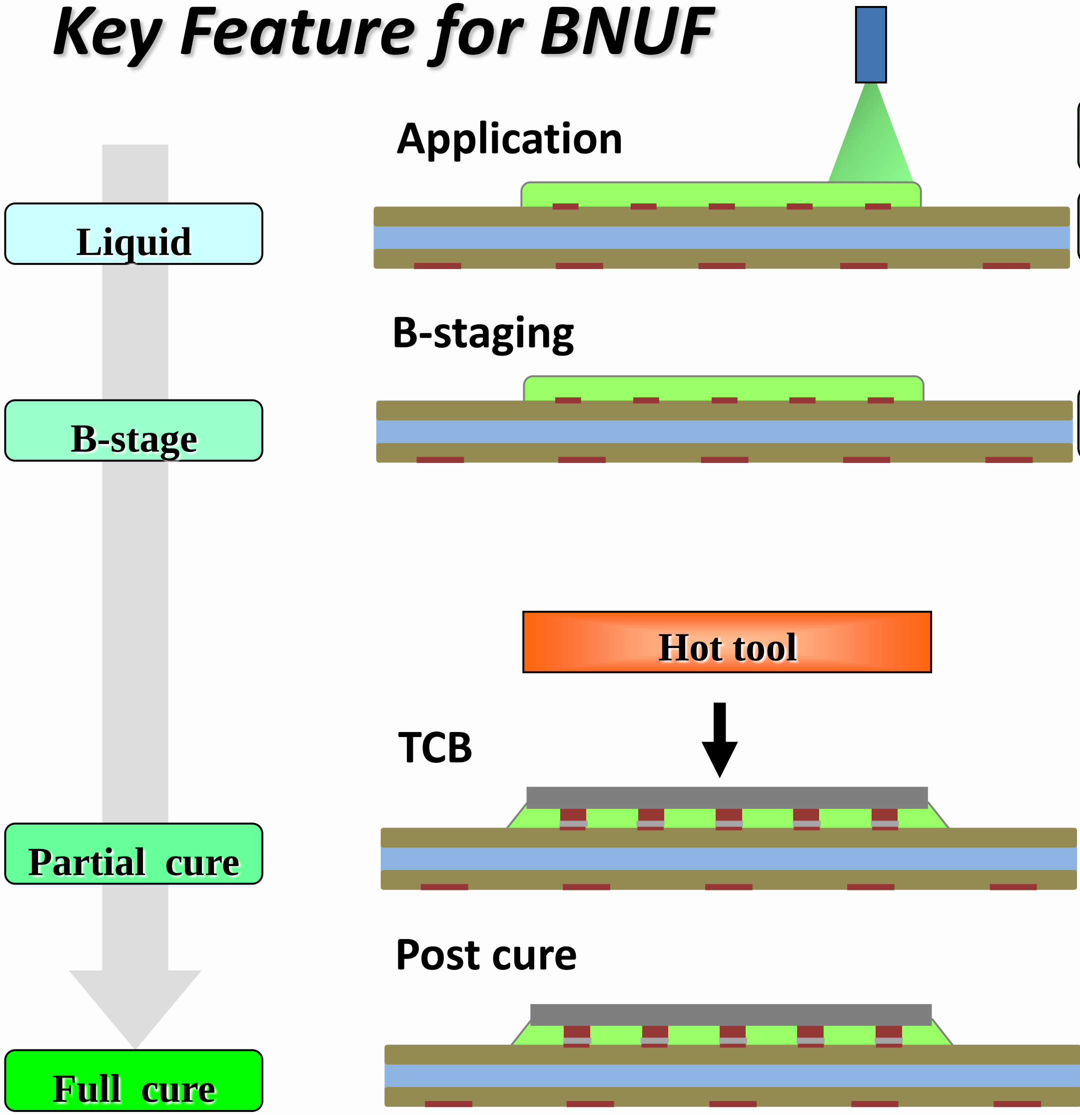
Fillet shape



B-Stage No Flow Underfill (BNUF) for 3D Packaging



Key Feature for BNUF

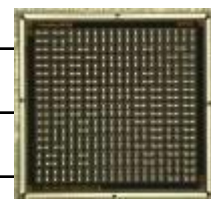


- Planer application [Dispensing, Spray, etc.]
- Excellent surface coverage
- Tack free @ RT
- Tacky @ TCB process
- Self fluxing
- High throughput for TCB process

Cross Section of BNUF after TCB

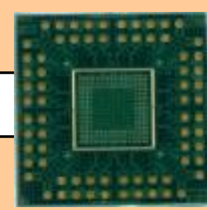
【Die】

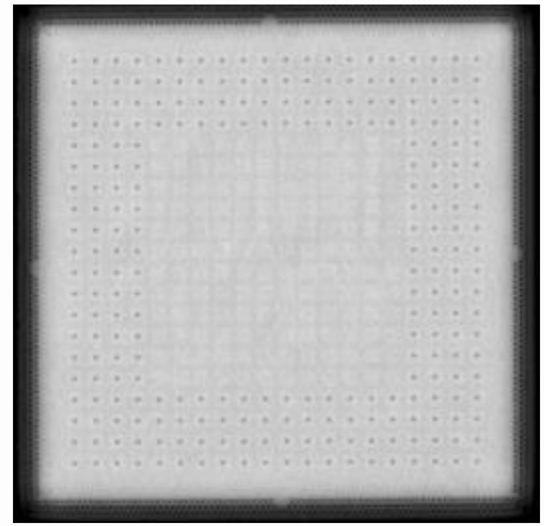
Size (mm)	7.3×7.3
Bump	Cu-pillar[t=30um] w/ Sn-Ag cap[t=15um]
Bump pitch (um)	peripheral 80
	core bump 300
Passivation	PI(PI2727)
Number of bump	peripheral 648
	core bump 400

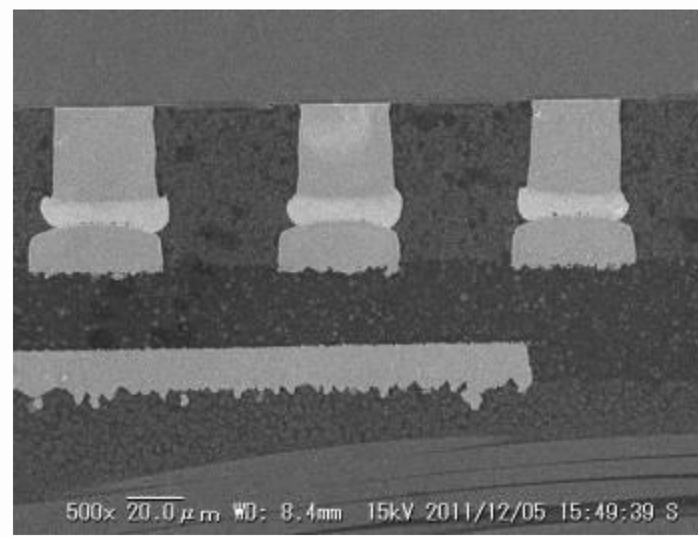


【substrate】

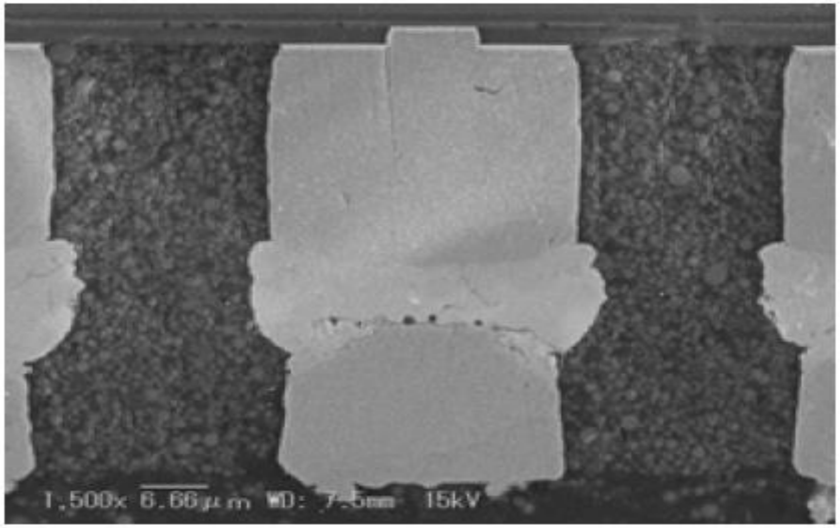
Surface treatment	Ni/Au







Filler Entrapment?

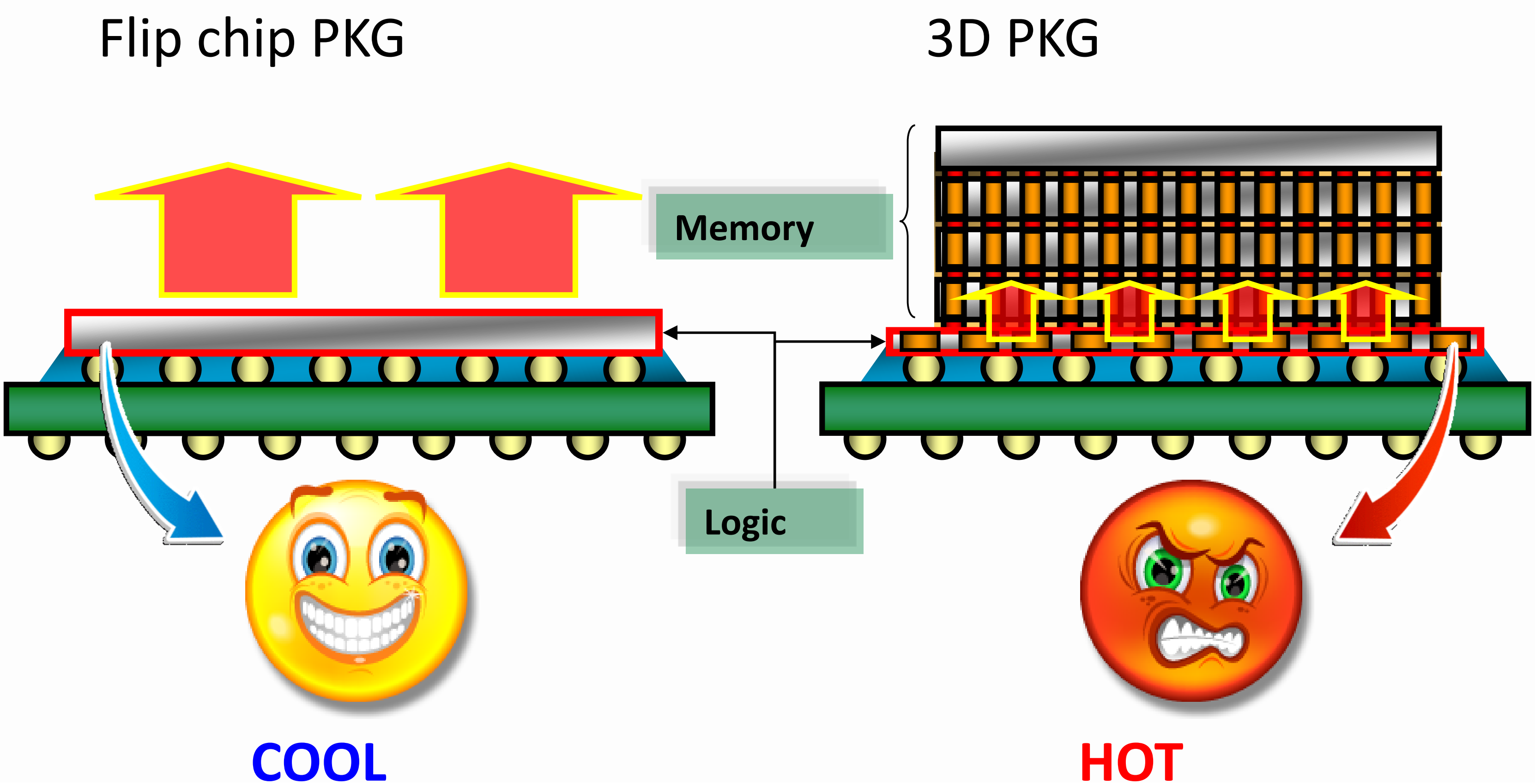


1000hrs

Thus far filler entrapment during the thermal compression bonding process has been seen, however there has been no ill effects to mechanical or electrical reliability.

Further finite element analysis might be necessary to determine when mechanical and electrical failures begin to occur.

Thermal Conductivity is Important for 3D packages

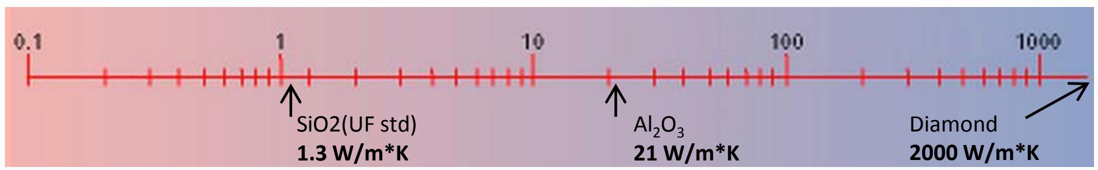


Since 3D package represents multiple heat sources that results in high thermal dispersion, underfill must improve thermal performance in order to collaborate with complex package design.

How Underfill Thermal Conductivity Can Be Improved

- *While replacing silica fillers with high thermal conductive fillers, underfill thermal conductivity improves.*

*Thermal conductivity (W/m*K)*

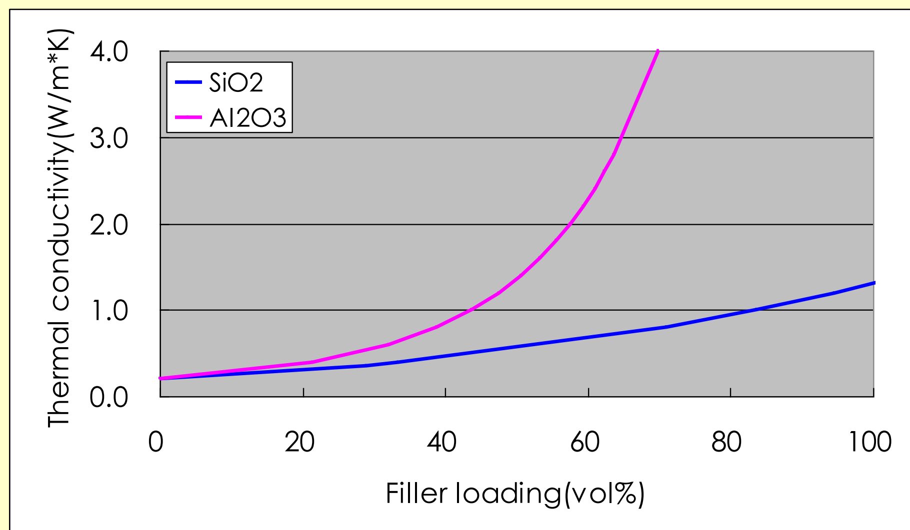


Thermal conductivity of Al2O3 is 16 times higher than SiO2.

Theory of Bruggeman

$$1-\phi = \frac{\lambda e - \lambda d}{\lambda c - \lambda d}\left(\frac{\lambda c}{\lambda e}\right)^{1/3}$$

Φ : Volume fraction of filler
λe : Thermal conductivity of composite
λc : Thermal conductivity of matrix
λd : Thermal conductivity of filler



Summary

- ✓ *CUF continues to evolve providing narrow gap penetration and jet dispense stability for high volume manufacturing.*
- ✓ *Voiding risk has been minimized due to pressure cure ovens and vacuum assist processing.*
- ✓ *Pre-applied materials, NCP, NCF, BNUF have different characteristics from CUF and can provide new assembly opportunities moving forward compared to std reflow technology. Hybrid manufacturing processes such as TCCUF also offer distinct advantages.*
- ✓ *Filler Entrapment during TCB thus far is not a major concern but warrants further study.*
- ✓ *High thermal conductivity materials are being examined once again in detail for 2.5/3D applications.*